77th Congress, 1st Session - - - - - House Document No. 13, pt. 1

ANNUAL REPORT OF THE BOARD OF REGENTS OF

THE SMITHSONIAN INSTITUTION

SHOWING THE

OPERATIONS, EXPENDITURES, AND CONDITION OF THE INSTITUTION FOR THE YEAR ENDED JUNE 30

1940

(Publication 3606)

UNITED STATES
GOVERNMENT PRINTING OFFICE
WASHINGTON : 1941

For sale by the Superintendent of Documents, Washington, D. C. - - - - - - Price $1.50 (cloth cover)

LETTER OF TRANSMITTAL

SMITHSONIAN INSTITUTION,
Washington, December 5, 1940.

To the Congress of the United States:

In accordance with section 5593 of the Revised Statutes of the United States, I have the honor, in behalf of the Board of Regents, to submit to Congress the annual report of the operations, expenditures, and condition of the Smithsonian Institution for the year ended June 30, 1940. I have the honor to be,

Very respectfully, your obedient servant,

C. G. ABBOT, *Secretary.*

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THE SMITHSONIAN INSTITUTION

June 30, 1940

Presiding officer ex officio.—FRANKLIN D. ROOSEVELT, President of the United States.

Chancellor.—CHARLES EVANS HUGHES, Chief Justice of the United States.

Members of the Institution:

FRANKLIN D. ROOSEVELT, President of the United States.
JOHN N. GARNER, Vice President of the United States.
CHARLES EVANS HUGHES, Chief Justice of the United States.
CORDELL HULL, Secretary of State.
HENRY MORGENTHAU, Jr., Secretary of the Treasury.
HARRY HINES WOODRING, Secretary of War.
ROBERT H. JACKSON, Attorney General.
JAMES A. FARLEY, Postmaster General.
CHARLES EDISON, Secretary of the Navy.
HAROLD L. ICKES, Secretary of the Interior.
HENRY A. WALLACE, Secretary of Agriculture.
HARRY LLOYD HOPKINS, Secretary of Commerce.
FRANCES PERKINS, Secretary of Labor.

Regents of the Institution:

CHARLES EVANS HUGHES, Chief Justice of the United States, Chancellor.
JOHN N. GARNER, Vice President of the United States.
CHARLES L. MCNARY, Member of the Senate.
ALBEN W. BARKLEY, Member of the Senate.
BENNETT CHAMP CLARK, Member of the Senate.
CHARLES L. GIFFORD, Member of the House of Representatives.
CLARENCE CANNON, Member of the House of Representatives.
WILLIAM P. COLE, Jr., Member of the House of Representatives.
FREDERIC A. DELANO, citizen of Washington, D. C.
R. WALTON MOORE, citizen of Virginia.
ROLAND S. MORRIS, citizen of Pennsylvania.
HARVEY N. DAVIS, citizen of New Jersey.
ARTHUR H. COMPTON, citizen of Illinois.
VANNEVAR BUSH, citizen of Washington, D. C.

Executive committee.—FREDERIC A. DELANO, R. WALTON MOORE.
Secretary.—CHARLES G. ABBOT.
Assistant Secretary.—ALEXANDER WETMORE.
Administrative assistant to the Secretary.—HARRY W. DORSEY.
Treasurer.—NICHOLAS W. DORSEY.
Chief, Editorial Division.—WEBSTER P. TRUE.
Librarian.—WILLIAM L. CORBIN.
Personnel officer.—HELEN A. OLMSTED.
Property clerk.—JAMES H. HILL.

UNITED STATES NATIONAL MUSEUM

Keeper ex officio.—Charles G. Abbot.
Assistant Secretary (in charge).—Alexander Wetmore.
Associate director.—John E. Graf.

SCIENTIFIC STAFF

Department of Anthropology:

Frank M. Setzler, head curator; A. J. Andrews, chief preparator.

Division of Ethnology: H. W. Krieger, curator; Arthur P. Rice, collaborator.

Section of Ceramics: Samuel W. Woodhouse, collaborator.

Division of Archeology: Neil M. Judd, curator; Waldo R. Wedel, assistant curator; R. G. Paine, senior scientific aid; J. Townsend Russell, honorary assistant curator of Old World archeology.

Division of Physical Anthropology: Aleš Hrdlička, curator; T. Dale Stewart, associate curator.

Collaborators in anthropology: George Grant MacCurdy; D. I. Bushnell, Jr.

Department of Biology:

Leonhard Stejneger, head curator; W. L. Brown, chief taxidermist; Aime M. Awl, illustrator.

Division of Mammals: Gerrit S. Miller, Jr., curator; Remington Kellogg, assistant curator; H. Harold Shamel, senior scientific aid; A. Brazier Howell, collaborator.

Division of Birds: Herbert Friedmann, curator; J. H. Riley, associate curator; H. G. Deignan, assistant curator; Alexander Wetmore, custodian of alcoholic and skeleton collections; Casey A. Wood, collaborator; Arthur C. Bent, collaborator.

Division of Reptiles and Batrachians: Leonhard Stejneger, curator; Doris M. Cochran, assistant curator.

Division of Fishes: Leonard P. Schultz, curator; E. D. Reid, senior scientific aid.

Division of Insects: L. O. Howard, honorary curator; Edward A. Chapin, curator; William Schaus, honorary assistant curator.

Section of Hymenoptera: S. A. Rohwer, custodian; W. M. Mann, assistant custodian; Robert A. Cushman, assistant custodian.

Section of Myriapoda: O. F. Cook, custodian.

Section of Diptera: Charles T. Greene, assistant custodian.

Section of Coleoptera: L. L. Buchanan, specialist for Casey collection.

Section of Lepidoptera: J. T. Barnes, collaborator.

Section of Hemiptera: W. L. McAtee, acting custodian.

Section of Forest Tree Beetles: A. D. Hopkins, custodian.

Division of Marine Invertebrates: Waldo L. Schmitt, curator; C. R. Shoemaker, assistant curator; James O. Maloney, aid; Mrs. Harriet Richardson Searle, collaborator; Max M. Ellis, collaborator; J. Percy Moore, collaborator; Joseph A. Cushman, collaborator in Foraminifera; Charles Branch Wilson, collaborator in Copepoda.

Division of Mollusks: Paul Bartsch, curator; Harald A. Rehder, assistant curator; Joseph P. E. Morrison, senior scientific aid.

Section of Helminthological Collections: Benjamin Schwartz, collaborator.

Division of Echinoderms: Austin H. Clark, curator.

DEPARTMENT OF BIOLOGY—Continued.

Division of Plants (National Herbarium): W. R. Maxon, curator; Ellsworth P. Killip, associate curator; Emery C. Leonard, assistant curator; Conrad V. Morton, assistant curator; Egbert H. Walker, aid; John A. Stevenson, custodian of C. G. Lloyd mycological collection.

Section of Grasses: Agnes Chase, custodian.

Section of Cryptogamic Collections: O. F. Cook, assistant curator.

Section of Higher Algae: W. T. Swingle, custodian.

Section of Lower Fungi: D. G. Fairchild, custodian.

Section of Diatoms: Paul S. Conger, custodian.

Associates in Zoology: C. Hart Merriam, Mary J. Rathbun, C. W. Stiles, Theodore S. Palmer, William B. Marshall, A. G. Böving.

Associate Curator in Zoology: Hugh M. Smith.

Associate in Marine Sediments: T. Wayland Vaughan.

Collaborator in Zoology: Robert Sterling Clark.

Collaborators in Biology: A. K. Fisher, David C. Graham.

DEPARTMENT OF GEOLOGY:

R. S. Bassler, head curator; Jessie G. Beach, aid.

Division of Physical and Chemical Geology (systematic and applied): W. F. Foshag, curator; Edward P. Henderson, assistant curator; Bertel O. Reberholt, senior scientific aid.

Division of Mineralogy and Petrology: W. F. Foshag, curator; Frank L. Hess, custodian of rare metals and rare earths.

Division of Stratigraphic Paleontology: Charles E. Resser, curator; Gustav A. Cooper, assistant curator; Marion F. Willoughby, senior scientific aid; Margaret W. Moodey, aid for Springer collection.

Section of Invertebrate Paleontology: T. W. Stanton, custodian of Mesozoic collection; Paul Bartsch, curator of Cenozoic collection.

Division of Vertebrate Paleontology: Charles W. Gilmore, curator; C. Lewis Gazin, assistant curator; Norman H. Boss, chief preparator.

Associates in Mineralogy: W. T. Schaller, S. H. Perry.

Associate in Paleontology: E. O. Ulrich.

Associate in Petrology: Whitman Cross.

DEPARTMENT OF ENGINEERING AND INDUSTRIES:

Carl W. Mitman, head curator.

Division of Engineering: Frank A. Taylor, curator.

Section of Transportation and Civil Engineering: Frank A. Taylor, in charge.

Section of Aeronautics: Paul E. Garber, assistant curator.

Section of Mechanical Engineering: Frank A. Taylor, in charge.

Section of Electrical Engineering and Communications: Frank A. Taylor, in charge.

Section of Mining and Metallurgical Engineering: Carl W. Mitman, in charge.

Section of Physical Sciences and Measurement: Frank A. Taylor, in charge.

Section of Tools: Frank A. Taylor, in charge.

Division of Crafts and Industries: Frederick L. Lewton, curator; Elizabeth W. Rosson, senior scientific aid.

Section of Textiles: Frederick L. Lewton, in charge.

Section of Woods and Wood Technology: William N. Watkins, assistant curator.

Section of Chemical Industries: Wallace E. Duncan, assistant curator.

Section of Agricultural Industries: Frederick L. Lewton, in charge.

DEPARTMENT OF ENGINEERING AND INDUSTRIES—Continued.

Division of Medicine and Public Health: Charles Whitebread, associate curator.

Division of Graphic Arts: R. P. Tolman, curator.

Section of Photography: A. J. Olmsted, assistant curator.

DIVISION OF HISTORY: T. T. Belote, curator; Charles Carey, assistant curator; Catherine L. Manning, philatelist.

ADMINISTRATIVE STAFF

Chief of correspondence and documents.—H. S. BRYANT.
Assistant chief of correspondence and documents.—L. E. COMMERFORD.
Superintendent of buildings and labor.—R. H. TREMBLY.
Assistant superintendent of buildings and labor.—CHARLES C. SINCLAIR.
Editor.—PAUL H. OEHSER.
Engineer.—C. R. DENMARK.
Accountant and auditor.—N. W. DORSEY.
Photographer.—A. J. OLMSTED.
Property clerk.—LAWRENCE L. OLIVER.
Assistant librarian.—LEILA F. CLARK.

NATIONAL GALLERY OF ART

President.—DAVID K. E. BRUCE.
Vice President.—FERDINAND LAMMOT BELIN.
Secretary and treasurer.—DONALD D. SHEPARD.
Director.—DAVID E. FINLEY.
Assistant director.—MACGILL JAMES.
Administrator.—H. A. MCBRIDE.
Chief Curator.—JOHN WALKER.

NATIONAL COLLECTION OF FINE ARTS

Acting director.—RUEL P. TOLMAN.

FREER GALLERY OF ART

Director.—JOHN ELLERTON LODGE.
Assistant director.—GRACE DUNHAM GUEST.
Associate in archeology.—CARL WHITING BISHOP.
Associate in research.—ARCHIBALD G. WENLEY.
Superintendent.—W. N. RAWLEY.

BUREAU OF AMERICAN ETHNOLOGY

Chief.—MATTHEW W. STIRLING.
Senior ethnologists.—H. B. COLLINS, JR., JOHN P. HARRINGTON, JOHN R. SWANTON.
Senior archeologist.—FRANK H. H. ROBERTS, JR.
Senior anthropologist.—JULIAN H. STEWARD.
Associate anthropologist.—W. N. FENTON.
Editor.—M. HELEN PALMER.
Librarian.—MIRIAM B. KETCHUM.
Illustrator.—EDWIN G. CASSEDY.

INTERNATIONAL EXCHANGES

Secretary (in charge).—CHARLES G. ABBOT.
Chief Clerk.—COATES W. SHOEMAKER.

NATIONAL ZOOLOGICAL PARK

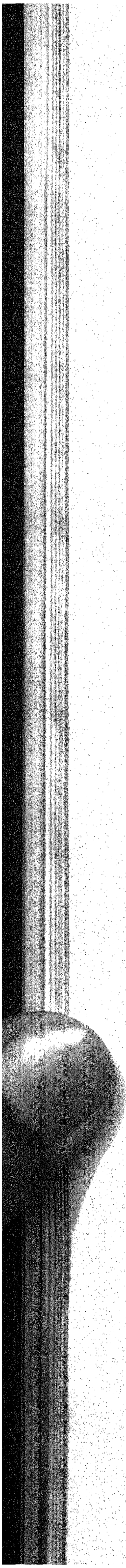
Director.—WILLIAM M. MANN.
Assistant director.—ERNEST P. WALKER.

ASTROPHYSICAL OBSERVATORY

Director.—CHARLES G. ABBOT.
Assistant director.—LOYAL B. ALDRICH.
Senior astrophysicist.—WILLIAM H. HOOVER.

DIVISION OF RADIATION AND ORGANISMS

Director.—CHARLES G. ABBOT.
Assistant director.—EARL S. JOHNSTON.
Senior physicist.—EDWARD D. MCALISTER.
Senior mechanical engineer.—LELAND B. CLARK.
Associate plant physiologist.—FLORENCE M. CHASE.
Junior biochemist.—ROBERT L. WEINTRAUB.



REPORT OF THE SECRETARY OF THE SMITHSONIAN INSTITUTION

C. G. ABBOT

FOR THE YEAR ENDED JUNE 30, 1940

To the Board of Regents of the Smithsonian Institution.

GENTLEMEN: I have the honor to submit herewith my report showing the activities and condition of the Smithsonian Institution and the Government bureaus under its administrative charge during the fiscal year ended June 30, 1940. The first 17 pages contain a summary account of the affairs of the Institution, and appendixes 1 to 11 give more detailed reports of the operations of the National Museum, the National Gallery of Art, the National Collection of Fine Arts, the Freer Gallery of Art, the Bureau of American Ethnology, the International Exchanges, the National Zoological Park, the Astrophysical Observatory, the Division of Radiation and Organisms, the Smithsonian Library, and of the publications issued under the direction of the Institution. On page 109 is the financial report of the executive committee of the Board of Regents.

OUTSTANDING EVENTS

The number of visitors to the buildings of the Institution and the National Museum during the year reached a new record total—2,506,171. The construction of the new National Gallery of Art Building, presented to the Nation by the late Andrew W. Mellon and designated a bureau of the Institution, was brought nearly to completion, and it is expected that the Gallery will be opened to the public early in 1941. The renovation of the galleries of the National Collection of Fine Arts, housed in the Natural History Building of the National Museum, was completed in October 1939, and the galleries were reopened to the public in that month. The Smithsonian radio program, "The World Is Yours," completed its fourth year on the air, continuing with undiminished popularity. An official Nation-wide poll taken during the year rated the program at the top of all noncommercial programs on all networks. In honor of Dr. John R. Swanton's fortieth year on the scientific staff of the Institution, there was published a volume of Essays in Historical Anthropology of North America prepared by members of the Institution's anthropological staff and dedicated to

Dr. Swanton. A bequest of approximately $130,000 came during the year from the estate of Mrs. Eleanor E. Witherspoon, of Washington, D. C. Two vacancies in the Board of Regents of the Institution were filled by the appointment of Senator Bennett Champ Clark, of Missouri, and Vannevar Bush, of Washington, D. C.

The enormous task of revising all solar-constant results from all observing stations from 1923 to the present was nearly completed at the close of the year, and it is expected to publish the final values during the coming year. The Division of Radiation and Organisms carried forward valuable experiments in the fundamental phenomenon of photosynthesis. Working plans have been prepared for the proposed Handbook of South American Indians to be published by the Institution under the editorship of Dr. Julian H. Steward.

Dr. W. M. Mann directed the Smithsonian-Firestone Expedition to Liberia for the purpose of collecting live animals for the National Zoological Park. Dr. Leonard P. Schultz accompanied the Navy Surveying Expedition to the Phoenix and Samoan Islands, bringing back 14,000 specimens of the fishes of that region. M. W. Stirling made a second archeological expedition to southeastern Mexico in cooperation with the National Geographic Society, uncovering many additional stone monuments, including one with an initial series date in the Maya calendar.

SUMMARY OF THE YEAR'S ACTIVITIES OF THE BRANCHES OF THE INSTITUTION

National Museum.—Appropriations for the maintenance and operation of the Museum for the year totaled $810,725, an increase of $32,345 over those for the previous year. Additions to the collections numbered 1,960 accessions, totaling 212,474 individual specimens, bringing the number of catalog entries in all departments to more than 17,000,000. Some of the outstanding accessions were: In anthropology, Eskimo and other artifacts from Siberia and northern Alaska, Bondu and Yoruba masks from West Africa and Nigeria, and a cast of a Neanderthal child skull from Uzbekistan; in biology, several varieties of seals from the Antarctic, collections of birds from Veracruz and Indochina, Mexican reptiles and amphibians collected by Dr. Hobart M. Smith, 14,000 fishes taken by Dr. Leonard P. Schultz in the Phoenix and Samoan Islands, the E. D. Ball collection of 75,000 specimens of Hemiptera, and 600 marine invertebrates from southeast Greenland collected by the Bartlett Greenland Expedition of 1939; in geology, a flawless aquamarine crystal weighing 347 grams, a 128-carat emerald crystal from Bahia, Brazil, and 495 Mexican minerals, a large collection of Paleozoic fossils made by Drs. G. A. Cooper and Josiah Bridge in 1939, and

25 original type specimens of fossil lizards received in exchange from the Peabody Museum of Natural History; in engineering and industries, a model of the *Yankee Clipper* and the first ticket issued to a fare-paying passenger on the initial public trans-Atlantic flight, a Gaulard and Gibbs transformer and an early Tesla motor, a collection of early incandescent lamps, and a Parsons turbine-electric generator; in history, the dress in the White House series worn by Dolly Madison, and many mementos, medals, and portraits of famous Americans, including Gen. Ulysses S. Grant, Gen. Philip H. Sheridan, Col. Charles A. Lindbergh, Madame Ernestine Schumann-Heink, and others. As usual, many expeditions were sent out in the furtherance of the Museum's work in anthropology, biology, and geology; these were largely financed by Smithsonian private funds or through cooperation with other organizations or individuals. Visitors to the various Museum buildings totaled 2,506,171, an all-time record for annual attendance. The year's publications included an annual report, 1 Bulletin, 1 Contributions from the United States National Herbarium, and 27 Proceedings papers. Twelve special exhibits were held under the auspices of various educational, scientific, and governmental agencies. Many members of the Museum staff participated actively in the Eighth American Scientific Congress held in Washington May 10 to 21, 1940.

National Gallery of Art.—At the annual meeting of the Board of Trustees held February 12, 1940, David K. E. Bruce was elected President and Ferdinand Lammot Belin Vice President of the Board for the ensuing year. New officials appointed during the year were Macgill James, Assistant Director, Charles Seymour, Jr., Curator of Sculpture, George T. Heckert, Assistant to the Administrator, and Sterling P. Eagleton, Chief Engineer and Building Superintendent. Satisfactory progress was made in organizing the Gallery staff, and this nucleus has been engaged in preparatory work, the compilation of catalogs, and the purchase of supplies and furniture. The Board of Trustees accepted a gift from The A. W. Mellon Educational and Charitable Trust of 11 celebrated paintings by early American artists, a first step toward setting up in the National Gallery a section devoted to the advancement and preservation of American art. The Board also accepted two fountain groups by Pierre Legros and Jean Baptiste Tubi, done in 1672 on orders of Louis XIV, one of which will be placed in each of the garden courts of the Gallery. Such work of repair and restoration of paintings as has been found necessary was done in New York by Stephen Pichetto, Consultant Restorer to the Gallery. A Publications Fund was established for the purpose of publishing cata-

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logs, handbooks, color reproductions, post cards, and similar material for the benefit of the public when the Gallery is opened. It is hoped that construction of the Gallery building will be completed in November of 1940. Several months will be required for decorating the exhibition rooms and installing the collections, so that formal opening of the Gallery to the public is expected to take place about March of 1941. It is estimated that the total cost of the building and landscaping will exceed $15,000,000.

National Collection of Fine Arts.—The complete renovation of the exhibition galleries, begun during the previous fiscal year, was finished in October 1939 and the galleries were reopened to the public on the 4th of that month. New backgrounds of monk's cloth, repainting of all woodwork and reflectors to match the backgrounds, and renovation and backing of all pictures combined to put the entire National Collection in excellent condition. The nineteenth annual meeting of the Smithsonian Art Commission was held on December 5, 1939. One painting, Young Girl with Dog, by Edward Percy Moran, a bequest of Alfred Duane Pell, was accepted for the National Collection. Three miniatures were acquired through the Catherine Walden Myer Fund. Several art works were lent upon request to other museums and organizations. The following seven special exhibitions were held: The Fifth Annual Metropolitan State Art Contest, 1939, comprising 272 exhibits of paintings, sculpture, and prints; 29 pastel and oil paintings by Esteban Valderrama; a miniature by Juan de Dios Hoyos; 83 pieces of wood turnings by James L. Prestini; 24 portraits and 5 drawings by John Slavin; 153 paintings by 31 members of the Landscape Club of Washington, D. C.; and 103 miniatures by 61 members of the Pennsylvania Society of Miniature Painters.

Freer Gallery of Art.—Additions to the collections included Chinese bamboo, bronze, jade, marble, painting, and pottery; East Indian and Arabic manuscripts; Iranian (Persian) and Syro-Egyptian metal work; and Indian and Persian painting. Curatorial work was devoted to the study and recording of these new acquisitions and of other material already in the collection. In addition, 1,093 objects of similar character and 263 photographs of others were brought or sent to the Director for information concerning them, and written or oral reports upon them were made to the owners. Changes in exhibition involved 40 individual objects. Visitors for the year numbered 108,770. Eight illustrated lectures were given in the auditorium by members of the staff. Eleven groups were given instruction in the study rooms, and seven groups were given docent service in the exhibition galleries. John Bundy, Superintendent of the Gallery for more than 21 years, died August 18, 1939; he was succeeded by Weldon N. Rawley.

Bureau of American Ethnology.—M. W. Stirling, Chief, continued his archeological excavations in southeastern Mexico in cooperation with the National Geographic Society. At Tres Zapotes the chronology of the site was satisfactorily determined; at Cerro de Mesa 20 carved stone monuments were located, including one with an initial series date in the Maya calendar; and at La Venta 20 monuments were unearthed, including 5 colossal heads, several beautifully carved altars, and some stelae. Dr. J. R. Swanton devoted most of the year to assembling material on the ethnology and early history of the Caddo Indians of Louisiana, Arkansas, Texas, and Oklahoma. Dr. John P. Harrington conducted linguistic and ethnological studies of the Kiowa Apache at Anadarko and Apache, Okla., the Navaho at Window Rock, Ariz., the Chipewyan of eastern Alberta, Canada, the Sarcee of southern Alberta, the Carrier, Chilcotin, and Nicola on the upper Fraser River, the Tlinkit of southeastern Alaska, and the Atchat, or Eyak, of the Gulf of Alaska. Dr. Frank H. H. Roberts, Jr., continued excavations at the Lindenmeier site in northern Colorado, where much additional evidence of the presence of Folsom man was obtained. Dr. Julian H. Steward, as editor of the proposed Handbook of South American Indians, drew up a working outline for this project. Toward the end of the year he went to British Columbia to study the Carrier Indians. Henry B. Collins, Jr., continued working over the prehistoric Eskimo material that he excavated around Bering Strait in 1936. Dr. William N. Fenton conducted ethnobotanical studies among the Iroquois Indians of New York and Canada. Miss Frances Densmore, a collaborator of the Bureau, completed for publication several manuscripts on Indian music. The Bureau published an annual report and three bulletins. The library received 364 accessions, and a large amount of material was reclassified and reshelved.

International Exchange Service.—The Exchange Service serves as the official agency for the United States for the exchange with foreign countries of governmental and scientific publications. It handled during the year 639,344 packages of such publications, weighing 527,545 pounds. These figures show a considerable decrease from the previous year, owing to the enforced curtailment of shipments to many foreign countries because of war conditions. At the close of the year, the exchange of publications was suspended between the United States and all European countries except Great Britain, Finland, and the Soviet Republic. Sets of United States governmental documents are now sent through the Exchange Service to 104 foreign depositories, and 104 copies of the Congressional Record and the Federal Register are sent to foreign countries in exchange for their official journals.

National Zoological Park.—A new restaurant building was begun during the year under an allotment of $90,000 from the P. W. A. It is expected to be completed during the fall of 1940. Other improvements included the construction of 9 new paddocks for various animals; a series of waterfowl ponds; an enclosure for lizards, snakes, crocodilians, and turtles; construction of 9,000 feet of curbing and 2,050 square feet of walks; and extensive planting of trees and shrubs in newly developed areas. Dr. Mann directed the Smithsonian-Firestone Expedition to Liberia, bringing back nearly 200 animals for the collections, including many rare forms. Malcolm Davis brought back a number of animals from India, including an Indian rhinoceros, the first to be shown at the Zoo. He also accompanied Admiral Byrd's Antarctic Expedition, bringing back a number of penguins for exhibition at the Zoo. Visitors for the year totaled 2,129,600, including classes from 628 different schools from 21 States and the District of Columbia. Of particular interest among the many gifts of the year were a pair of black bears from the Pennsylvania Game Commission, obtained through Carl La Barre, of Portland, Pa.; three Finsches' tree kangaroos from Richard Archbold, of the American Museum of Natural History, New York; a pair of yak from the Department of Mines and Resources, Dominion of Canada, through Hoyes Lloyd; and a group of pheasants from Carlo Zeimet, of Washington, D. C. There were 55 mammals born, 28 birds hatched, and 22 reptiles born or hatched during the year. The total number of animals in the collection was 2,550, representing 762 different species. The Zoo's greatest need is for three new buildings to replace antiquated structures now in use.

Astrophysical Observatory.—The work of the Observatory in studying the radiation of the sun has been continued during the year at Washington and at the three observing stations at Tyrone, N. Mex., Table Mountain, Calif., and Montezuma, Chile. Work has been continued throughout the year on the complete revision of all results on the solar constant of radiation from all stations and from 1923 to the present time. Many small inconsistencies requiring extensive study made progress slow in preparing final tables of mean values of the solar constant. It is now hoped to publish these tables as volume 6 of the Annals of the Observatory during the coming year. Mathematical investigations at Harvard and at the Massachusetts Institute of Technology tend to confirm the reality of periodicities in solar variation as found by Dr. Abbot. Six lectures on his studies of solar radiation were given by Dr. Abbot at the Harvard College Observatory, and the first four are in course of publication in the Bulletin of the American Meteorological Society. Dr. H. Arctowski, eminent meteorologist of Poland, who was in Washington when his

country was conquered and his property lost, was retained on the staff of the Observatory for 1 year through funds provided by John A. Roebling. Soon after beginning his work Dr. Arctowski became convinced of the reality of solar variation and that it is the major factor in weather, and he published two papers summarizing his findings. Dr. Abbot endeavored to evaluate the separate influences produced on weather by long-range solar periodicities. It soon appeared that considerable weather changes were produced by the periodicities, and changes in phase of the weather responses were found to be due to seasonal influences. Five-year forecasts, using only meteorological periodicities antedating 1935, showed a marked correlation between the forecast and the event. In the forecast for precipitation at Peoria, Ill., a correlation coefficient of 70 ± 5 percent was found between prediction and event. It is hoped that further study may improve the 5-year synthetic forecasts.

Division of Radiation and Organisms.—In continuation of its investigations on the relation of light to plant growth, the Division carried forward a number of promising experiments, particularly in the field of photosynthesis. A large number of simultaneous measurements were made of the rate of carbon dioxide uptake and the intensity of fluorescence during the induction period of photosynthesis. These showed very interesting results, and further work along this line is proposed, for it is felt that fluorescence is a useful tool in the study of the mechanism of photosynthesis. Respiration and chlorophyll studies have been continued with the recording spectrographic carbon dioxide apparatus. The perfecting of instruments and technique has progressed to a point where detailed work on the problems relating to the genesis of chlorophyll and the beginning of photosynthesis may be carried on. A standardized technique has been worked out for the extraction of growth substances from the oat seedling which has proved to have a number of advantages over other methods. A number of biochemical substances and plant extracts have been tested in the study of the growth of excised oat shoots and leaves. The maximum light sensitivity of the oat mesocotyl was shown to occur in the red region of the spectrum. Algae exposed four times to stimulative amounts of certain wave lengths of ultraviolet light showed 4 to 4.8 times the growth rate (expressed as number of cells) of the control cultures. The stimulated cells were less sensitive to lethal amounts of ultraviolet than the unstimulated cells. This and other results of experiments on the effects of ultraviolet on algae will be published during the coming year. Three papers by members of hte Division's staff were published during the year.

THE ESTABLISHMENT

The Smithonian Institution was created by act of Congress in 1846, according to the terms of the will of James Smithson, of England, who in 1826 bequeathed his property to the United States of America "to found at Washington, under the name of the Smithsonian Institution, an establishment for the increase and diffusion of knowledge among men." In receiving the property and accepting the trust, Congress determined that the Federal Government was without authority to administer the trust directly, and, therefore, constituted an "establishment" whose statutory members are "the President, the Vice President, the Chief Justice, and the heads of the executive departments."

THE BOARD OF REGENTS

Changes in the Board of Regents during the year included the appointment on January 4, 1940, by the Vice President, as President of the Senate, of Senator Bennett Champ Clark, of Missouri, to succeed Senator M. M. Logan, of Kentucky, who died October 3, 1939, and the appointment by joint resolution of Congress approved April 5, 1940, of Vannevar Bush, of Washington, D. C., as a citizen regent to succeed John C. Merriam, who resigned December 14, 1939.

The roll of regents at the close of the year was as follows: Charles Evans Hughes, Chief Justice of the United States, Chancellor; John N. Garner, Vice President of the United States; members from the Senate—Charles L. McNary, Alben W. Barkley, Bennett Champ Clark; members from the House of Representatives—Charles L. Gifford, Clarence Cannon, William P. Cole, Jr.; citizen members—Frederic A. Delano, Washington, D. C.; R. Walton Moore, Virginia; Roland S. Morris, Pennsylvania; Harvey N. Davis, New Jersey; Arthur H. Compton, Illinois; and Vannevar Bush, Washington, D. C.

Proceedings.—The annual meeting of the Board of Regents was held on January 11, 1940. The regents present were Chief Justice Charles Evans Hughes, Chancellor; John N. Garner, Vice President of the United States; Senator Charles L. McNary; Representatives Charles L. Gifford, Clarence Cannon, and William P. Cole, Jr.; citizen regents Frederic A. Delano, R. Walton Moore, Harvey N. Davis, and Arthur H. Compton; and the Secretary, Dr. Charles G. Abbot.

The Board received and accepted the annual report of the Secretary, covering activities during the year of the parent institution and of the several Government branches; the report by Mr. Delano of the executive committee, covering financial statistics of the Institution, and of the permanent committee, which handles matters connected with the investment of the Institution's various funds; and the an-

nual report of the Smithsonian Art Commission. Mr. Delano also presented the report of the Smithsonian Gallery of Art Commission, established by the act of May 17, 1938, providing a site for the proposed Smithsonian Gallery of Art and for other purposes including the selection of designs, by competition or otherwise, for the building. The Deficiency Act of June 25, 1938, appropriated $40,000 for the use of the Commission. The Board received the report for consideration and approved the selection of Eliel Saarinen as the architect of the building.

The Board formally approved the acceptance of the Samuel H. Kress gift of Italian art by the Smithsonian Institution for the National Gallery of Art, and also a plan for old-age and incapacitation pensions for the private employees in the Institution.

In his usual special report the Secretary mentioned briefly the more important activities carried on by the Institution and its branches during the year.

FINANCES

A statement on finances will be found in the report of the Executive Committee of the Board of Regents, page 109.

MATTERS OF GENERAL INTEREST

SMITHSONIAN RADIO PROGRAM

June 9, 1940, marked the completion of 4 years of the Smithsonian radio program, "The World Is Yours." A pioneer in the field of popularizing science, invention, history, and art by means of dramatized radio broadcasts, this series has been put on the air through the cooperation of the Smithsonian Institution, the United States Office of Education, the National Broadcasting Co., and the Works Projects Administration. Beginning with only a few stations, "The World Is Yours" has steadily increased in popularity in all parts of the country until today it is carried every Sunday on some 80 stations of the N. B. C. red network. Over half a million letters have been received from listeners, the great majority of whom are enthusiastic in their commendation of the program.

The greatest tribute ever paid the series came in the spring of 1940. A leading radio-audience research service, upon completing a Nation-wide analysis of the size of the listening audiences of all programs on all networks, gave "The World Is Yours" the highest rating among all sustaining programs on the air. This is a very gratifying indication that science, history, and other cultural fields arouse Nation-wide interest when presented in popular form.

In selecting the program subjects, the Smithsonian Institution endeavors to create a well-rounded series that in the course of a year

will present to listeners topics relating to every major branch of science. Exploration, history, industrial progress, and art are also included, although less frequently, as coming within the scope of Smithsonian activities or exhibits. The list of subjects for the past fiscal year is as follows:

	1939
French Soldiers in the American Revolution	July 2
Red Men of the Great Plains	July 9
Birds in the Service of Man	July 16
Story of Fossils	July 23
Ryder, the Artist and Man	July 30
Stars in the Sky	Aug. 6
Early Air Mail	Aug. 13
Life of the Honey Bee	Aug. 20
Glaciers	Aug. 27
Story of the Street Car	Sept. 3
Lizards, Survivors of an Ancient Animal Kingdom	Sept. 10
Early American Fashions	Sept. 17
World's Most Valuable Trees	Sept. 24
King Salmon	Oct. 1
The Indians Who Met Columbus	Oct. 8
The Marvels of Sound	Oct. 15
Earthquakes	Oct. 22
Story of Portland Cement	Oct. 29
Germanna Ford—Crossroads of History	Nov. 5
The Great Apes	Nov. 12
Flying in Safety	Nov. 19
Our Debt to the Indians	Nov. 26
Exploring the Amazon for Plants	Dec. 3
Historical Gems	Dec. 10
Cortez, the Conquistador	Dec. 17
Christmas at Mount Vernon	Dec. 24
First New Year in the Colonies	Dec. 31
	1940
The March of Science	Jan. 7
Rise of the Railroad	Jan. 14
Harnessing Electromagnetism	Jan. 21
Volcanoes	Jan. 28
The American Bison and the Indian	Feb. 4
Story of Hard Money in Ancient Times	Feb. 11
Evolution of the Typewriter	Feb. 18
Pompeii Lives Again	Feb. 25
Radium	Mar. 3
Conquest of Noise	Mar. 10
Our Changing Wildlife	Mar. 17
American Pharmacy—First-line Defense Against Disease	Mar. 24
Opening of the Far West	Mar. 31
American Inventors	Apr. 7
Science in the Field	Apr. 14
Dinosaurs—Giants of the Past	Apr. 21
Story of Corn	Apr. 28
100 Years of Postage Stamps	May 5
Whistler: The Artist and the Man	May 12

	1940
Wilkes: An American Who Discovered a Continent	May 19
Story of Airships	May 26
How Fossils Serve Mankind	June 2
Bats—Animals that Fly	June 9
Natives of Hawaii	June 16
Bering in the Far North	June 23
The Smithsonian Today	June 30

From the beginning an attempt has been made to supply listeners who request it with supplementary information on the subject covered by each broadcast. This supplementary material has been issued in a number of forms—mimeographed, multigraphed, and printed—but the difficulty has been to print sufficient copies with the funds available. In October 1939 a new method was tried—that of publishing the "listener-aids" in magazine form through the cooperation of Columbia University Press and selling them to listeners at cost. This method proved to be very successful and was continued through June 30, when publication of the magazine was suspended for the summer months. After February, the articles printed in the magazine were written by Smithsonian experts and were illustrated with reproductions of photographs. The average circulation over the 9-month period was between 3,000 and 4,000 per week.

The W. P. A. financial assistance given during the 4 years the program has been on the air was withdrawn at the close of the past year. The W. P. A. funds had been used to pay the salaries of the production and music directors, a large proportion of the actors, and all of the clerical force in Washington who handled "The World is Yours" mail. Rather than let the program die for lack of funds, N. B. C. generously agreed to finance all the production costs for the coming year, so that hereafter "The World is Yours" will be presented as an N. B. C. public-service feature. The script writer will be paid by the Smithsonian, as for the past 2 years.

Much experience has been gained during the 4 years of the Smithsonian radio program. The quality of the broadcasts has been steadily improved, and their popularity has continued unabated. It is the hope of the Institution that "The World is Yours" may stay on the air indefinitely.

ANTHROPOLOGICAL PUBLICATION IN HONOR OF JOHN R. SWANTON'S FORTIETH YEAR WITH THE INSTITUTION

In 1900 Dr. John R. Swanton joined the scientific staff of the Bureau of American Ethnology, a branch of the Smithsonian Institution. The year 1940, therefore, marks the fortieth year of his association with the Institution, and to commemorate the occasion,

there was published a volume entitled "Essays in Historical Anthropology of North America." This book, comprising 600 pages of text, 16 halftone plates, and 36 text figures, contains 13 essays by members of the Institution's staff, an analysis of Dr. Swanton's own work by Dr. A. L. Kroeber, an introduction by Dr. Julian H. Steward, and a bibliography of Swanton's published contributions to anthropology. Each contributor, taking the field with which he has been particularly concerned, presents a survey of the anthropology of that area, stressing the historical phases of the study. As a whole, the volume covers a large part of the North American Continent, with, however, notable gaps such as the lower Mississippi region and the Pacific coast.

Dr. Swanton, knowing nothing of the preparation of this volume of essays in his honor, was invited on May 25, 1940, to attend a meeting of the staffs of the Institution and the Bureau of American Ethnology in the regents' room. At this meeting I presented him with a specially bound copy of the volume and expressed to him on behalf of his colleagues our admiration of his outstanding achievements in the field of historical anthropology. This was also expressed in the foreword to the published volume, prepared and signed by me, which reads:

> It is a real satisfaction for the Smithsonian Institution to publish this collection of papers in historical anthropology in honor of Dr. John R. Swanton, on the occasion of his fortieth year with the Institution. Diligence, modesty, and kindliness combine with great ability in his make-up, and lead all his colleagues and friends to love him, at the same time that they honor his scholarship and his basic contributions to American anthropology.
>
> While the attractive field of deductive speculation has in the past lured many American anthropologists, Swanton has been content to gather information and, sifting it, to lay a foundation where others may securely build. Treating particularly the history of cultures and of tribal movement in the Southeast since the discovery of America, Swanton's publications in this field will ever be the classic sources, basic to future advances.

WALTER RATHBONE BACON TRAVELING SCHOLARSHIP

The Walter Rathbone Bacon traveling scholarship of the Smithsonian Institution was held for a second year by Dr. Hobart M. Smith. The purpose of Dr. Smith's work, as stated last year, is the accumulation of specimens of reptiles and amphibians from Mexico, on the basis of which a herpetology of Mexico may be compiled and the biotic provinces of the country more accurately defined.

Collecting was continued during the year, and included the vicinity of Piedras Negras, Guatemala, and certain parts of the Mexican states of Chiapas, Oaxaca, Veracruz, Guerrero, Michoacán, Mexico, Puebla, and Hidalgo. By June 30, 1940, the collection numbered approximately 17,000 specimens, and represented some 475 species.

Eight new species of frogs, lizards, and snakes have been described by Dr. Smith from the collection. In addition, Dr. E. H. Taylor has described two other species of frogs from the collection.

SMITHSONIAN MAIN HALL EXHIBITS

In my last annual report it was stated that I had appointed a committee, consisting of Messrs. Mitman, chairman, Foshag, Friedmann, Setzler, and True, all of the Institution's staff, to recommend plans for exhibits in the Smithsonian main hall to illustrate all the work of the Institution and to make clear to visitors the relationship between the parent Institution and its various branches. The committee met weekly, beginning in the summer of 1939, and its first recommendation was for the complete redecoration of the hall, using a plastic paint that would give the effect of old stone. The exhibits and bookcases previously in the main hall were removed, and new walls were constructed at the east and west ends of the hall to conceal the steel bookstacks constructed many years ago for the use of the Smithsonian Library. The redecoration was completed in the spring of 1940.

The committee's recommendation as to the exhibits themselves, submitted on March 30, 1940, was approved by me, and the committee was instructed to carry out the plans, the entire exhibit to be ready in time for the next annual meeting of the Board of Regents on January 17, 1941.

The plan proposed by the committee comprised eight alcoves and four quadrants to be constructed completely around the hall, leaving the central aisle clear for the easy circulation of visitors. The eight alcoves are to portray in popular form the work of the Institution in astronomy, geology, biology, radiation and organisms, physical anthropology, cultural anthropology, engineering and industries, and art. The four quadrants, enclosing the central area of the hall, will illustrate the scope of Smithsonian activities, the National Zoological Park, history, and the organization and branches of the Institution. The former children's room, adjoining the main hall on the south, will be used to illustrate the Institution's work in the diffusion of knowledge.

At the close of the year, construction of the backgrounds for the exhibits was well under way, and the details of the exhibits themselves were being worked out for prompt installation when the construction work is completed.

NINTH ARTHUR LECTURE

The Arthur lecture, under the auspices of the Institution, was provided for in the will of the late James Arthur, of New York, who in 1931 left to the Smithsonian Institution a sum of money, part of the

income from which should be used for an annual lecture on some aspect of the study of the sun.

The ninth Arthur lecture, "Solar Prominences in Motion," by Robert R. McMath, Director of the McMath-Hulbert Observatory of the University of Michigan, was given in the auditorium of the National Museum on the evening of January 16, 1940. The lecture was illustrated with moving pictures of the sun. It will be published in full with illustrations in the 1940 Smithsonian Report.

The eight previous lectures in the series given under the Arthur fund were as follows:

1. The Composition of the Sun, by Henry Norris Russell, Professor of Astronomy at Princeton University. January 27, 1933.
2. Gravitation in the Solar System, by Ernest William Brown, Professor of Mathematics at Yale University. January 25, 1933.
3. How the Sun Warms the Earth, by Charles G. Abbot, Secretary of the Smithsonian Institution. February 26, 1934.
4. The Sun as a Typical Star, by Walter S. Adams, Director of the Mount Wilson Observatory. December 18, 1934.
5. Sun Rays and Plant Life, by Earl S. Johnston, Assistant Director of the Division of Radiation and Organisms, Smithsonian Institution. February 25, 1936.
6. Discoveries from Eclipse Expeditions, by Samuel Alfred Mitchell, Director of the Leander McCormick Observatory, University of Virginia. February 9, 1937.
7. The Sun and the Atmosphere, by Harlan True Stetson, Research Associate, Massachusetts Institute of Technology. February 24, 1938.
8. Sun Worship, by Herbert J. Spinden, Curator of American Indian Art and Primitive Cultures, Brooklyn Museums. February 21, 1939.

WITHERSPOON BEQUEST

In May 1940 the Institution received approximately $130,000, the residuary estate of the late Eleanor E. Witherspoon, of Washington, D. C. The paragraph in Mrs. Witherspoon's will relating to this bequest reads as follows:

> All the rest, residue and remainder of my estate, of every kind and description, real and personal, wheresoever and howsoever situated, now possessed or that may hereafter be acquired by me, including any lapsed or void legacy or devise, I give, devise and bequeath absolutely and in fee simple, unto the Smithsonian Institution, to be held by it as a fund to be known as the Thomas A. Witherspoon Memorial, in memory of my late beloved husband, with full power in said Institution of managing, controlling, investing and reinvesting the same, and sale of all or any part of the corpus thereof, and of any investment or reinvestment thereof, and the net income therefrom to be used for the advancement of human knowledge, with the single exception that no part of the corpus of the trust fund created in this Sixteenth Paragraph hereof or the income therefrom shall be used in collecting birds and animals dead or alive or for purposes of vivisection.

This generous bequest is a most welcome addition to the Institution's resources for research, exploration, and publication, and the wishes of the testatrix in respect to it will be scrupulously observed.

EXPLORATIONS AND FIELD WORK

In the furtherance of its investigations in many branches of science, the Smithsonian sent out or cooperated in 19 expeditions, which worked not only in many States in the United States but also in a number of foreign lands as well.

Dr. W. F. Foshag continued his survey of the mines and mineral localities of Mexico and added valuable mineralogical specimens to the Smithsonian's collection, now the greatest assemblage of Mexican ores and minerals extant. Dr. C. Lewis Gazin directed an expedition to central Utah in search of remains of extinct vertebrate ainmals and particularly to investigate the Cretaceous and Paleocene formations exposed along the east side of the Wasatch Plateau. Drs. Josiah Bridge and G. Arthur Cooper visited localities in Utah, Nevada, Texas, and the Midwest to collect Paleozoic fossils, needed to fill gaps in the National Museum collection, and also to examine and collect from Lower Ordovician sections in the western States in order to obtain more exact information for use in the interregional correlation of these rocks. Dr. Cooper also spent a month studying the rocks and fossils of the Middle Ordovician in the Southern Appalachians. James H. Benn quarried out and brought to Washington for study a large slab of beautifully preserved fossil sea urchins (echinoids) from the bluffs bordering Chesapeake Bay at Port Republic, Md.

Dr. W. M. Mann conducted an expedition to the Argentine to collect live animals for the National Zoological Park; the trip resulted in the addition of 316 specimens to the collection, a number of which had never before been exhibited at the Zoo. Dr. Alexander Wetmore collected birds in southern Mexico, gaining information on the distribution of variable forms and on the movements of northern migrants. W. M. Perrygo collected birds and mammals in North Carolina to fill gaps in the National Museum's study collection, and H. G. Deignan visited European museums to study type material and other relevant specimens in connection with his work on the birds of Siam. Dr. Leonard P. Schultz accompanied the Navy Surveying Expedition to the Phoenix and Samoan Islands and obtained, in addition to 14,000 fishes, many hundreds of specimens of the fauna and flora of the region. At the invitation of Capt. G. Allan Hancock, Dr. Waldo L. Schmitt participated in the expedition to the north coast of South America, where boat dredging and shore collecting resulted in the acquisition of valuable specimens of marine life. Capt. Robert A. Bartlett, on his annual summer trip to the Arctic, collected for the Institution a quantity of material, including five specimens of a very rare 10-armed starfish. Austin H. Clark continued his study of the butterflies of Virginia, collecting many fine specimens including one species new to the Virginia fauna.

Ellsworth P. Killip collected plants in Colombia in continuation of the Smithsonian's special study of the flora of that country. About 11,000 specimens were obtained, including 300 numbers of ferns and more than 100 numbers each of orchids, aroids, grasses, and peppers.

Dr. Aleš Hrdlička spent several months studying anthropological material in the museums of England, Russia, Siberia, and France. The main object of the work in Russia, where most of his time was spent, was to examine such skeletal and cultural materials from Siberia as might have a bearing on the problem of Asiatic-American connections.

Dr. T. Dale Stewart continued excavations at Patawomeke, the Virginia Indian village visited by Capt. John Smith in 1608, discovering a type of pottery unlike that prevailing on the surface, and an ossuary. Dr. Waldo R. Wedel conducted an archeological survey in western Kansas to determine the extent of Puebloan influence in that area and to examine the prospects for injecting time perspective into the earlier archeological history of the region. Dr. Frank H. H. Roberts, Jr., continued excavations at the Lindenmeier site in northern Colorado, producing much further evidence of the presence of the ancient Folsom man, but failing again to discover any skeletal remains of Folsom man himself. Dr. William N. Fenton carried on ethnobotanical studies among the Iroquois of New York State and Canada, giving particular attention to Iroquois medicine.

PUBLICATIONS

The principal means of carrying out the "diffusion of knowledge," one of the Institution's primary functions, is its series of publications. From its private funds, the Institution issues the Smithsonian Miscellaneous Collections, a series containing all the scientific papers published by the Institution proper; from Government funds are issued the Smithsonian Annual Report (with general appendix reviewing progress in science), the Bulletins and Proceedings of the National Museum, the Bulletins of the Bureau of American Ethnology, the Annals of the Astrophysical Observatory, and Catalogs of the National Collection of Fine Arts. The Freer Gallery of Art series, Oriental Studies, is supported by Freer Gallery funds.

During the past year, the Institution and its branches issued a total of 78 publications, of which 45 were issued by the Institution proper, 30 by the National Museum, and 3 by the Bureau of American Ethnology. Information as to titles, authors, and other details of these publications will be found in the report of the Chief of the Editorial Division, appendix 11. The total number of publications distributed was 146,156.

LIBRARY

The accessions to the Smithsonian Library during the past year were 7,709 volumes and pamphlets, bringing the total holdings to 907,816, exclusive of several thousand incomplete or unbound items. The exchange work of the library was seriously handicapped by abnormal conditions abroad; many foreign publications have been suspended or discontinued altogether. Among the larger gifts of the year were 897 publications from the American Association for the Advancement of Science, 653 from the Geophysical Laboratory of the Carnegie Institution of Washington, 252 from the American Association of Museums, and 216 from James Townsend Russell, Jr. The staff made 26,422 periodical entries, cataloged 6,105 publications, prepared and filed 42,388 catalog and shelf-list cards, loaned 11,745 publications to members of the staff of the Institution and its branches, and materially advanced the Union Catalog. Besides adding to the index of all Smithsonian publications and that of exchange relations, they began a third during the year; namely, a card index of all Smithsonian explorations. The needs of the library are for more funds for binding, more shelf room, and more personnel.

Respectfully submitted.

C. G. ABBOT, *Secretary.*

APPENDIX 1

REPORT ON THE UNITED STATES NATIONAL MUSEUM

SIR: I have the honor to submit the following report on the condition and operation of the United States National Museum for the fiscal year ended June 30, 1940.

Funds provided for the maintenance and operation of the National Museum for the year totaled $810,725, or $32,345 more than for the previous fiscal year. The amount was reduced $5,500 however, by reason of a compulsory administrative reserve. In addition to the normal expenditures of the Museum, a deficiency appropriation made $270,000 available to cover expenses in changing the electric current for the Smithsonian group of buildings from direct to alternating, and for installing new elevators in the Smithsonian and Natural History Buildings.

COLLECTIONS

Additions to the great collections of the National Museum were received in 1,960 separate accessions, totaling 212,474 individual specimens. These were distributed among the five departments as follows: Anthropology, 5,233; biology, 168,673; geology, 33,921; engineering and industries, 2,019; and history, 2,628. For the most part these acquisitions were gifts from individuals or represented expeditions sponsored by the Smithsonian Institution. All are listed in detail in the full report on the Museum, published as a separate document, but the more important are summarized below. The total number of catolog entries in all departments now slightly exceeds 17,000,000.

Anthropology.—Archeological material came from many parts of the world: Eskimo and other artifacts from Siberia and northern Alaska, stone and shell artifacts from Guam and Mexico, objects from various parts of Egypt, and potsherds and casts from Argentina. In ethnology, many objects were received representing the cultures of the Eskimos and of various Plains and western Indian tribes. Africa was represented by Bondu and Yoruba masks from West Africa and Nigeria, respectively. The section of ceramics received 146 specimens; musical instruments, 12, including a violin designed and constructed in the anthropological laboratory by Nicola Reale, partly along the lines of a late Stradivarius; period art and textiles, 153, including many fine pieces of lace, ivory, and silver. In the division of physical anthropology the following accessions are noteworthy:

Cast of a Neanderthal child skull from Uzbekistan, a neolithic skull from Siberia, 8 trephined skulls from Peru, and casts of upper paleolithic crania from the Choukoutien caves near Peiping, China.

Biology.—A total of 168,673 biological specimens were accessioned during the year, a number less than last year owing presumably to the disturbed condition of the world. Important mammalian material consisted of 8 Weddell and 2 crab-eating seals and 1 leopard-seal skull from the Antarctic, several cetacean skulls and fetuses from Alaska and the Antarctic, 101 bats from Mexico and Guatemala, 10 mammals from the Smithsonian-Firestone Expedition to Liberia, and many small mammals collected from North Carolina, District of Columbia, Maryland, and Massachusetts. The George S. Huntington collection of nonhuman skeletons was transferred from the Army Medical Museum.

Avian accessions from Veracruz and Indochina were outstanding. Over 1,000 bird specimens resulted from the field work conducted by the Museum in North Carolina. Other lots were representative of Italian, Chilean, Paraguayan, Antarctic, and Samoan forms.

Large collections of reptiles and amphibians were made in Mexico by Dr. Hobart M. Smith under the Walter Rathbone Bacon traveling scholarship of the Smithsonian Institution. Forty-one specimens from Liberia were sent by Dr. W. M. Mann from the Smithsonian-Firestone Expedition; 240 Maryland reptiles and amphibians were donated; and an important lot of Jamaican and Cayman Island material was purchased.

The most noteworthy ichthyological addition consisted of 14,000 fishes collected by Curator Leonard P. Schultz as a member of the Navy Surveying Expedition to the Phoenix and Samoan Islands in 1939. Dr. W. M. Mann forwarded 462 fishes collected at Gibi Mountain, Liberia. A large number of paratypes of fishes was received in exchange from the Academy of Natural Sciences of Philadelphia, the Bernice P. Bishop Museum at Honolulu, the Field Museum of Natural History at Chicago, and the British Museum of Natural History.

In insects several large collections were added: The E. D. Ball collection of approximately 75,000 specimens of Hemiptera; about 63,000 miscellaneous insects transferred from the Bureau of Entomology and Plant Quarantine, and 20,000 more received directly by specialists or additions resulting from collecting trips; about 30,000 specimens of mites (on 3,000 slides) from the collections of the late A. P. Jacot, transferred from the Forest Service; 6,000 Chinese insects from Dr. D. C. Graham; and an important collection of about 2,000 coccinellid beetles of the genus *Hippodamia* from the distinguished coleopterist Prof. Th. Dobzhansky.

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Nearly 600 marine invertebrates from southeast Greenland came as a result of the Bartlett Greenland Expedition of 1939. In addition, there were received important collections of isopods, amphipods, sponges, pycnogonids, and worms, many representing new species or species new to the Museum collections. Mollusks came chiefly from Cuba, Hawaii, Jamaica, Samoa, Guam, Colombia, Ecuador, and the United States. Accessions of helminths included type material of much interest. Among the echinoderms was a fine series of starfishes, sea urchins, brittlestars, and holothurians from Antarctica, as well as noteworthy specimens from the Indo-Pacific.

About 23,600 plants, largely American, were received for inclusion in the National Herbarium, the largest lot being 5,200 specimens from Virginia, West Virginia, and Maine presented by H. A. Allard, of the United States Bureau of Plant Industry.

Geology.—Several additions to the mineralogical and petrological series were made possible by the Canfield, Roebling, and Chamberlain funds of the Smithsonian Institution. Among these were a flawless, pale blue, aquamarine crystal weighing 347 grams; a 128-carat emerald crystal from Bahia, Brazil; and 495 Mexican minerals, including rare arsenates and associated minerals and fine apatite crystals from Durango. These latter were collected by Curator W. F. Foshag on a trip to Mexico in 1939. About 3,000 mineral, ore, and rock specimens were transferred from the United States Military Academy. Forty-one individual specimens were contained in 21 accessions of meteorites received, 30 of these representing falls new to the collections.

The largest accession in the field of stratigraphic paleontology comprised the Paleozoic fossils collected by Assistant Curator G. A. Cooper and Dr. Josiah Bridge during their 1939 field work. Next in point of size is the celebrated old English Calvert collection of fossils procured by Martin L. Ehrmann. In addition, the biologic study collections were materially augmented with many fossil echinoderms, conodonts, Foraminifera, bryozoans, brachiopods, and mollusks received from generous donors. The most important exhibition specimen of the year was a 3- by 7-foot slab of Miocene standstone, discovered by Dr. Foshag at Scientists Cliff, Md., on which a rare species of echinoid covered the surface.

From a scientific standpoint, the most noteworthy accession in the division of vertebrate paleontology was an exchange from the Peabody Museum of Natural History of 25 original type specimens of fossil lizards, making the National Museum collection of these saurians the largest assemblage of its kind in this country. Field expeditions yielded four articulated lizard skeletons, two partial ceratopsian skulls from the North Horn formation, and a considerable number of fragmentary jaws and teeth from the Paleocene

of central Utah. The type of *Delphinus calvertensis* originally belonging to the National Institute, but lent to Louis Agassiz prior to 1852, was returned to the National collections by the Museum of Comparative Zoology.

Engineering and industries.—In the section of aeronautics additions were made to the collection of aircraft propellers, including one of the first controllable-pitch propellers issued for practical service. A model of the *Yankee Clipper* from the Pan American Airways System and the first ticket issued to a fare-paying passenger on the initial public trans-Atlantic flight also were received, as well as a number of aircraft models. To the section of electrical engineering and communications came the following: A Gaulard and Gibbs transformer and an early Tesla motor, both important contributions to the practical use of alternating current; a collection of early incandescent lamps; and a Parsons turbine-electric generator, thought to be the oldest of the original form of the Parsons turbine now in existence except for the first one at the Science Museum in London. Many miscellaneous objects pertaining to transportation, communication, metrology, mining, and metallurgy, tools and crafts, medicine and public health, and chemistry continue to come in as gifts and loans, always welcome additions to these sections. To the division of graphic arts there was transferred from the Government Printing Office an iron printing press invented by Peter Smith in 1822. Other interesting material received in this division pertained to motion-picture photography and projection, color photography, fine printing and bookmaking, and photoengraving.

History.—Over 2,600 objects of historic and antiquarian interest were accessioned, including mementos, medals, and portraits of such outstanding figures as General Lafayette, Gen. Ulysses S. Grant, Gen. Philip H. Sheridan, Maj. Gen. George H. Thomas, Col. Charles A. Lindbergh, Madame Ernestine Schumann-Heink, and others. The handsome dress in the White House series worn by Dolly Madison was presented to the Museum by Mrs. Charles D. Walcott and the Smithsonian Institution. A unique addition to the historical collection was the five flags flown by the *Yankee Clipper* on the first official flight of that plane from Port Washington, N. Y., to Southampton, England, and return in May 1939, presented through the Hon. R. Walton Moore. The numismatic collection was increased by 408 coins and medals and the philatelic collection by 2,038 foreign postage stamps, cards, and envelopes transferred from the Post Office Department. Also there came the famous A. Eugene Michel collection of postal stationery, which comprises 144 volumes of material containing about 40,000 specimens.

EXPLORATIONS AND FIELD WORK

The work of the staff in the field was wide and varied in scope and was carried on principally through funds made available through the Smithsonian Institution. The field studies thus arranged are one of the most important sources of new materials for the National Museum and result in new facts and information of many kinds.

Anthropology.—On April 15, 1939, Dr. Aleš Hrdlička, curator of physical anthropology, left New York on an anthropological trip to Europe, with particular emphasis on studies in Russia and Siberia. The main objects of a visit to London were to see the remains of early man from Palestine and whatever Siberian skeletal material there might be in the museums of that city. In France the main purpose was to see the newly established Museum of Man in Paris. In Russia and Siberia the chief objective was to examine such skeletal and cultural materials from Siberia as might have a bearing on the problem of Asiatic-American connections. The main part of the trip was in the Soviet Union, where the stay was divided between Leningrad, Moscow, and Irkutsk. In the anthropological institutes and museums of these cities, Dr. Hrdlička found exceedingly rich and valuable materials from Siberia, all of which he was allowed to utilize freely.

The examinations in Leningrad were carried on in the new Anthropological Institute and Museum, which has a very large and valuable collection of human crania and skeletons, including important series of skulls of the Chukchi and other Siberian peoples. In the Anthropological Institute of the Moscow University there is another huge cranial and skeletal collection, including other important series of Siberian materials. Finally, at the Irkutsk Museum there is a large and very important collection of neolithic skeletal remains from the Angara River and Baikal Lake regions.

The Siberian crania examined and measured included large and particularly interesting series of the Chukchi, Ostiaks, Tungus, and the neolithics of the Irkutsk region. Dr. Hrdlička had the further privilege, partly at Leningrad and partly at Moscow, of seeing the skull, remains of bones, and associated cultural materials of a Neanderthal child from Uzbekistan, in central Asia. This is a find of outstanding anthropological importance, and the skull, lower jaw, and teeth are in excellent condition.

To determine, first, the extent of Puebloan influence in western Kansas and, second, the prospects for injecting time perspective into the earlier archeological history of the region, Dr. Waldo R. Wedel, assistant curator of archeology, extended into the High Plains an archeological survey begun in Kansas in 1937. A month was spent in and near Scott County State Park. Traces of a seven-room pueblo ruin opened by Williston and Martin in 1898 were relocated. Middens

yielded potsherds and artifacts of stone, bone, and horn, as well as rare objects of copper, iron, and glass. Charred maize and squash gourd rinds indicate horticulture, but quantities of animal bones suggest that subsistence was primarily by hunting. Contrary to expectations, Puebloan influences were almost negligible. Aside from the stone-walled ruin and nearby prewhite irrigation ditches, there was a bare handful of sherds, some painted, and a few incised clay pipe fragments presumably attributable to late Southwestern stimulus. Numerous bell-shaped roasting pits and large irregular trash pits, as also the great bulk of artifacts recovered, show close relationship to sites of the prehistoric Dismal River culture of southwestern Nebraska. No houses of indigenous type were found. Whatever the relationship between these remains and the Pueblo structure, it is an interesting historical fact that in early contact times the western plains were inhabited by Apache and Comanche bands, some of whom appear to have followed a semihorticultural mode of life.

Just outside the north entrance to the Park a small burial ground, probably much older than the above, yielded two long-headed skeletons and several secondary interments. With the skeletons were broken tortoise shells, tubular bone beads, and chipped flints, including one heavy-stemmed arrowpoint of woodland type. Persistent search failed to disclose any evidence of an associated village or camp site.

About 20 miles east, on Salt Creek in Lane County, Kans., remains of a different type were found. On and just below the surface of one site were materials attributable to the Upper Republican culture of southern Nebraska. Two small pit houses, each with four center posts, were worked out. Along with shallow middens nearby, they yielded typical pottery, arrowpoints, a bone fishhook, and other materials, but no direct proof of horticulture. Separated from this deposit by a barren stratum up to a foot thick was a second cultural layer. From this came thick cord-roughened sherds and large-stemmed arrowpoints markedly unlike the top-layer materials. This second horizon, evidently linked with some Plains woodland manifestation, had been intruded by both pit houses. Lack of time precluded investigation of what may be a third cultural horizon underlying both of the above.

These researches seem to show that in Lane and Scott Counties there were at least two groups of prehistoric pottery-making peoples. On stratigraphic grounds, those bearing a woodland culture preceded others with Upper Republican affiliations; neither appears to have been in contact with southwestern peoples. Still later, in protohistoric times, a third complex, assignable to the Dismal River culture, occupied the area. This sequence parallels that in western

Nebraska and adds materially to the geographic range of the cultures involved.

Dr. T. Dale Stewart, associate curator of physical anthropology, continued systematic excavations at the site of the Indian village located in Stafford County, Va., visited by Capt. John Smith in the summer of 1608 and described by him under the name of Patawomeke. Indications were that it had been a stockaded village. Among the details of the town plan that remained undiscovered at the close of the 1938 season were the main entrances, the location of the dwellings, and the manner of their construction. The cultural objects obtained during this work, as well as those found previously by Judge Graham, showed considerable uniformity, and thereby suggested a relatively short occupancy of the site. Nothing thus far gave indication of the presence here of cultural elements differing from those apparent on the surface. Nevertheless, a further development of the town plan in itself was deemed of sufficient importance for continuing the investigation in 1939. Constant presence at the site permitted the employment of a somewhat different technique from that used last year. Trenches 10 feet broad were extended across undisturbed parts of the site. This increased exposure, in contrast to the previous short 5-foot trenches, clarified the picture considerably. The initial trenches were run in the field to the east that had been under cultivation last season. Here it was hoped to find an entrance to the stockade, but none was found. As elsewhere about the site, the post holes are so numerous, presumably as a result of replacements and relocations, that the details are obscured. Some time was devoted also to trenching the accumulated refuse along the bluff overlooking the creek. In places these deposits reach 4 feet in depth, but give evidence of having received accretions from the plow.

Attention was distracted from these features toward the close of the season by two important finds of a different nature, a deep pit, containing a type of pottery unlike that prevailing on the surface, and an ossuary. The finding of the ossuary offered the opportunity to expose the bones from above in order to show their arrangement. Circumstances usually do not allow time for this procedure. In the present case a good record was made of about one-third of the burial pit before heavy and prolonged rains interrupted. A typical method of contracting the body appears to have been that in which the lower legs were flexed forward unnaturally at the knees so that the feet came to touch the abdomen. Two other features of the ossuary are of interest: At one place there was a mass of charred bones, the remains perhaps of a deliberate cremation or sacrifice. In connection with some of the skeletons there were great numbers of shell beads, and in one of these cases the largest beads had been placed within the skull, obviously at the time of burial.

Biology.—Field work in the study of the distribution and collection of birds and mammals of North Carolina, begun in the spring of 1939 and continued until July, was opened again in the fall for a period of a little over 2 months with W. M. Perrygo in charge of the party and Charles L. Wheeler as assistant. Dr. Wetmore and Mr. Graf visited the party when the men were located near Mattamuskeet in October, and spent several days with them. The work was concluded toward the close of November, with important collections as the result. In the spring of 1940 Mr. Perrygo was dispatched for similar work in the field in South Carolina, Southgate Hoyt serving as assistant throughout the period, with John Calhoun also as a member of the party during the early part of the summer. All this work was carried on under the W. L. Abbott fund.

In continuation of work in the vicinity of the archeological camp at Tres Zapotes, Veracruz, begun last year by Dr. Wetmore, M. A. Carriker, Jr., was engaged in making collections of birds in this area from January to May. The resulting collections, together with those that were obtained by Dr. Wetmore, constitute the most valuable series of birds yet assembled from this interesting area. Mr. Carriker during this season made collections in the region of the Tuxtla Mountains, which have been proposed for a national park, and also supplemented his series from Tres Zapotes with material from Tlacotalpan and from the coastal region south of Alvarado. The investigations were carried on under the W. L. Abbott fund.

Dr. Hobart M. Smith, traveling under the Walter Rathbone Bacon traveling scholarship of the Smithsonian Institution, continued throughout the year an exploration and study of the herpetological fauna of Mexico, covering systematically that interesting region. As a result of his work many beautifully prepared reptiles and amphibians have been received at the Museum. Dr. Smith was still in the field at the close of the fiscal year.

Dr. Leonard P. Schultz, detailed to accompany the U. S. S. *Bushnell* as naturalist on the Naval expedition to the Phoenix and Samoan Islands during the summer of 1939, returned on August 18 with large collections consisting of about 14,000 fishes, besides mollusks, coelenterates, echinoderms, worms, and other marine invertebrates, reptiles, birds, mammals, and plants aggregating 2,000 or 3,000 specimens.

As in past years, Capt. Robert A. Bartlett in his annual expedition to Greenland waters brought to the Museum further valuable additions to the invertebrate collections besides a noteworthy collection of Arctic plants.

Austin H. Clark continued his work on the survey of the butterfly fauna of Virginia, visiting different localities during the summer of 1939 and the spring of 1940.

Upon invitation of the Venezuelan Government, Mrs. Agnes Chase, custodian of grasses, was detailed to Venezuela in February for the purpose of studying the grasses of that country and recommending plans for agrostological research. Field work was carried out successfully in the western, northern, and eastern parts of the country during a stay of 6 weeks. Notwithstanding an almost unprecedented drouth, about 1,500 specimens were collected. Continuing his study of the flora of Big Pine Key, Fla., E. P. Killip, associate curator of the National Herbarium, accompanied by Robert F. Martin, of the Department of Agriculture, spent a period of 2 weeks there in midwinter. To the 208 species of plants discovered on three earlier visits, 32 were added, and many duplicates were collected for general distribution.

Geology.—Dr. W. F. Foshag, curator of physical and chemical geology, spent August 1939 collecting minerals in Mexico, confining his studies largely to the states of Nuevo Leon and Durango. Mapimi and Cerro Mercado, in the state of Durango, yielded exceptionally fine material, notably the rare arsenates of iron from upper workings of the Ojuela mine recently reopened by Mexican miners, and fine apatite crystals and associated minerals from Cerro Mercado. Among other localities visited were Banderas, Cabrellas, Higueras, Diente, Zimapan, Guanajuato, and Queretaro. After the Instituto Geologico de Mexico had deducted its selection, eight cases were shipped to Washington.

Late in September, Dr. G. A. Cooper, assistant curator of stratigraphic paleontology, joined Dr. Josiah Bridge, of the United States Geological Survey, in Salt Lake City, Utah, whence they journeyed to Logan, where Dr. J. S. Williams, of Utah State Agricultural College, assisted them in the study of that region. The classic area for Cambrian, Lower Ordovician, and Devonian fossils, near Eureka, Nev., was visited, and 12 days were spent with Dr. T. S. Nolan and party, of the United States Geological Survey. Next, Las Vegas, Nev., furnished Lower Ordovician collections for future studies of that little-known area. The Devonian rocks at Silver City, N. Mex., were next examined and excellent fossils collected. From here the party proceeded to El Paso and Van Horn, Tex., obtaining Lower Ordovician fossils from the El Paso limestone; then to Marathon and the Glass Mountains, where 5 days were devoted to collecting silicified Permian fossils. The Central Hill country of Texas was visited for Cambrian fossils, and Mineral Wells for deposits of Pennsylvanian age. Turning homeward by way of the Arbuckle Mountains and Criner Hills, Okla., they devoted a week to collecting Middle Ordovician fossils. Dr. Cooper continued to Lower Ordovician outcrops in south-central Missouri and the Silurian of Little Saline Valley in east-central Missouri.

The season's work was brought to a close with collecting in the Wabash region of Indiana, where Silurian fossils were obtained from reefy masses near Peru, and in southern Indiana from Devonian and Mississippian rocks. Although the purpose of this long trip was to build up the weak parts of the study series of invertebrate fossils, equally important was the information obtained for definite placement stratigraphically of the Museum sets of fossils obtained in the days when such correlation was not so accurate. The Lower Ordovician fossils from Nevada and Texas, Permian of Texas, Pennsylvanian of central Texas, and Silurian from east-central Missouri and north-central Indiana, resulting from this trip, were all new to the collections.

Dr. E. O. Ulrich, associate in paleontology, in order to further his stratigraphic studies of Appalachian Valley geology and to test certain conclusions before publication, spent the month of September in field work in the southern section of the area, and a shorter time in June in Pennsylvania. Good collections were made, but most important was the information obtained to place stratigraphically the Museum's older sets of fossils.

In the division of vertebrate paleontology, C. W. Gilmore was detailed early in the spring of 1940 to accompany Earl Trager, of the National Park Service, on a reconnaissance trip to the site of a proposed national park in the Big Bend region of Texas. Although no collections were made, the area was determined as a field of much promise for dinosaur remains. The main field operations of the year for this division were conducted by Dr. C. Lewis Gazin, assistant curator, who left Washington early in June 1939 to head an expedition into the Upper Cretaceous and Paleocene regions of Utah, a continuation in part of two previous seasons of field work. In the upper Cretaceous along the westerly slope of North Horn Mountain, several partially articulated lizard skeletons and two incomplete ceratopsian skulls were among the specimens collected. In the Paleocene numerous fragmentary mammal specimens, consisting chiefly of jaw fragments and teeth, were obtained. As many of the latter represented new forms of multituberculates, taeniodonts, and other primitive forms, this collection contributes much information to the fauna of the Dragon formation.

Early in June 1940 Dr. Gazin left to continue the work in the Paleocene of Utah in the vicinity of North Horn Mountain and then to the Eocene of the Bridger Basin of Wyoming.

MISCELLANEOUS

Visitors.—A total of 2,506,171 visitors at the various Museum buildings was recorded for the year. This is 271,826 more than the number for the previous year and represents an all-time record

for annual attendance. This year the high months were July and August 1939, when 360,599 and 400,719 visitors, respectively, were recorded. The attendance in the four Museum buildings was as follows: Smithsonian Building (closed to visitors from January 2 to June 30, 1940), 200,113; Arts and Industries Building, 1,261,808; Natural History Building, 809,661; Aircraft Building, 233,589.

Publications and printing.—The sum of $27,100 was available during 1940 for the publication of the Museum Annual Report, Bulletins, and Proceedings. Thirty publications were issued—the Annual Report, 1 Bulletin, 1 Contributions from the United States National Herbarium, and 27 separate Proceedings papers. Particularly outstanding were the following: Variations and Relationships in the Snakes of the Genus *Pituophis*, by Olive Griffith Stull (Bull. 175); The Hederelloidea, a Suborder of Paleozoic Cyclostomatous Bryozoa, by Ray S. Bassler; Observations on the Birds of Northern Venezuela and Notes on the Birds of Kentucky, by Alexander Wetmore; Catalog of Human Crania in the United States National Museum Collections: Indians of the Gulf States, by Aleš Hrdlička; Trematodes from Fishes Mainly from the Woods Hole Region, Massachusetts, by Edwin Linton; and A Prehistoric Roulette from Wyandotte County, Kansas, by Waldo R. Wedel and Harry M. Trowbridge.

Volumes and separates distributed during the year to libraries, institutions, and individuals throughout the world aggregated 65,962 copies.

W. P. A. assistance.—As in previous years workers were assigned from the Works Progress Administration of the District of Columbia to assist the Museum staff in miscellaneous activities. On July 1, 1939, 144 assistants were so engaged, and on April 15, 1940, when the project was terminated owing to shortage of funds, these workers numbered 126. The service performed totaled 169,848 man-hours for the year. Conclusion of the project was felt in all departments of the Museum. Aside from the care given by the W. P. A. help in arranging and preserving the study collections, the cataloging and numbering of specimens were of direct aid to research, for the material thus handled became readily available for study by our own staff and by other technical workers.

Special exhibits.—Twelve special exhibits were held during the year under the auspices of various educational, scientific, and governmental agencies. In addition the department of engineering and industries arranged 23 special displays—2 in engineering, 9 in graphic arts, and 12 in photography.

Participation in scientific congress.—Members of the Museum staff actively participated in the Eighth American Scientific Congress,

which was held in Washington May 10 to 21, 1940, under the auspices of the United States Government and which brought together distinguished scientists from all the Pan American Republics. Dr. Alexander Wetmore served as the Secretary General to the Congress, working with officials of the State Department. Dr. C. G. Abbot and Dr. T. Wayland Vaughan were members of the organizing committee, and the latter was chairman of the geological section. All Museum curators were designated official delegates, and two members of the Museum staff—Frank M. Setzler and Paul H. Oehser—were detailed as secretaries; Austin H. Clark served as science press-relations officer. Dr. Aleš Hrdlička was a member of the section committee on anthropology. At various technical sessions of the Congress papers were presented by the following Museum scientists: Dr. Aleš Hrdlička, Dr. T. Dale Stewart, Dr. Remington Kellogg, Dr. Waldo L. Schmitt, and Dr. Paul Bartsch.

CHANGES IN ORGANIZATION AND STAFF

In the Department of Anthropology, Andreas J. Andrews was promoted October 1, 1939, to chief preparator in anthropology, succeeding W. H. Egberts, who retired.

In the Department of Biology, Herwil M. Bryant was appointed as junior biologist on September 29, 1939, and assigned to duty with the United States Antarctic Service. Through the retirement of Mrs. M. S. Clapp, Miss Vendla M. Hendrickson was promoted June 1, 1940, to clerk-stenographer in the Head Curator's office. Other changes in this Department included the promotion of Herbert G. Deignan to assistant curator in the Division of Birds on June 16, 1940, of Mrs. Aime M. Awl to principal scientific illustrator on June 1, 1940, and of Charles S. East to scientific aid on March 1, 1940.

In the library, Miss Marie Ruth Wenger was promoted to library assistant, on November 16, 1939.

Two honorary appointments on the Museum staff were made during the year, as follows: Dr. Stuart H. Perry as associate in mineralogy, and Dr. Adam G. Böving as associate in zoology.

Under the superintendent of buildings and labor Harry S. Jones was raised to principal mechanic (foreman of electricians) on September 1, 1939, and Sherley F. Williams to senior mechanic (senior electrician) on October 1, 1939. George W. Sharman was promoted to senior mechanic (senior sheet-metal worker), on September 16, 1939.

Floyd B. Kestner of the photographic laboratory was made assistant photographer on November 16, 1939.

Eleven employees left the service through the operation of the retirement act, seven of these for age, as follows: Leonard C. Gunnell, assistant librarian, on May 31, 1940, with 33 years 11 months of serv-

ice; William H. Egberts, chief preparator, on September 30, 1939, with 25 years 1 month of service; Mrs. Mary S. Clapp, clerk-stenographer, on May 31, 1940, with 19 years 11 months of service; Frank J. Cross, senior mechanic (tinner), on August 31, 1939, with 19 years 9 months of service; James F. Cudmore, lieutenant of guard, on June 30, 1940, with 21 years 3 months of service; William J. Snellings, guard, on December 31, 1939, with 18 years 5 months of service; and Willis Lanier, laborer-messenger, on August 31, 1939, with 24 years 7 months of service. Lewis E. Perry, shipper, on June 30, 1940, retired at his own request with 25 years 3 months of service. Three persons were retired for disability: Micajah W. Knight, guard, on November 30, 1939; William J. Myers, guard, on October 10, 1939; and Alberta Jackson, attendant, on August 31, 1939.

Dr. Willard W. Hill, assistant curator, Division of Ethnology, resigned to enter other service on January 18, 1940.

The year was marked by the loss of Dr. Cyrus Adler, associate in historic archeology, who died in Philadelphia, Pa., on April 7, 1940. Dr. Adler had been associated with the Smithsonian Institution over 50 years. Dr. Maynard M. Metcalf, since March 12, 1925, a collaborator in the Division of Marine Invertebrates, died on April 19, 1940.

Respectfully submitted.

Alexander Wetmore, *Assistant Secretary.*

Dr. Charles G. Abbot,

Secretary, Smithsonian Institution.

APPENDIX 2

REPORT OF THE NATIONAL GALLERY OF ART

SIR: I have the honor to submit, on behalf of the Board of Trustees of the National Gallery of Art, the third annual report of the Board covering its operations for the fiscal year ended June 30, 1940. Such report is being made pursuant to the provisions of the act of March 24, 1937 (50 Stat. 51), as amended by the public resolution of April 13, 1939 (Pub. Res. No. 9, 76th Cong.).

Under the act of March 24, 1937, Congress created, in the Smithsonian Institution, a bureau to be directed by a board to be known as the "Trustees of the National Gallery of Art," charged with the maintenance and administration of the National Gallery of Art.

In addition, Congress appropriated to the Smithsonian Institution the area bounded by Seventh Street, Constitution Avenue, Fourth Street, and North Mall Drive (now Madison Drive) Northwest, in the District of Columbia, as a site for a National Gallery of Art and authorized the Smithsonian Institution to permit The A. W. Mellon Educational and Charitable Trust, a public charitable trust, established by the late Hon. Andrew W. Mellon, of Pittsburgh, Pa., to construct thereon a building to be designated the "National Gallery of Art." Further, the act authorizes the Board to accept, for the Smithsonian Institution, and to hold and administer gifts, bequests and devises of money, securities, or other property for the benefit of the National Gallery of Art. To date two great collections of outstanding works of art have been received by the Trustees of the Gallery; namely, the Mellon Collection and the Samuel H. Kress Collection, which will be housed and exhibited in the Gallery building now being constructed in Washington. Under the creating act, the United States is pledged to provide such funds as may be necessary for the upkeep of the National Gallery of Art and the administrative expenses and costs of operation thereof, including the protection and care of the works of art so that the Gallery shall at all times be properly maintained and the works of art exhibited regularly to the general public.

ORGANIZATION AND STAFF

The statutory members of the Board are the Chief Justice of the United States, the Secretary of State, the Secretary of the Treasury, and the Secretary of the Smithsonian Institution, ex officio, and five

general trustees. The general trustees, serving during the fiscal year ended June 30, 1940, were David K. E. Bruce, Duncan Phillips, Ferdinand Lammot Belin, Joseph E. Widener, and Samuel H. Kress.

At the annual meeting of the Board held February 12, 1940, David K. E. Bruce was elected President and Ferdinand Lammot Belin was elected Vice President of the Board to serve for the ensuing year. Other executive officers continuing in office were Donald D. Shepard, Secretary-Treasurer and General Counsel, David E. Finley, Director, Harry A. McBride, Administrator, and John Walker, Chief Curator. At the same meeting the Board elected Macgill James of Baltimore, Maryland, to be Assistant Director. Mr. James has been serving as Director of the Municipal Museum of the City of Baltimore and is well qualified by experience and training to perform the duties of Assistant Director of the National Gallery of Art. Mr. James will begin his Gallery duties in the near future.

Other officers of the Gallery appointed during the year were Charles Seymour, Jr., formerly Instructor of History of Art and History in the Department of Fine Arts at Yale University, as Curator of Sculpture; George T. Heckert, as Assistant to the Administrator; and Sterling P. Eagleton, as Chief Engineer and Building Superintendent.

The three standing committees of the Board, provided for in the bylaws, as constituted at the annual meeting of the Board held February 12, 1940, are:

EXECUTIVE COMMITTEE

Chief Justice of the United States, Charles Evans Hughes.
Secretary of the Smithsonian Institution, Dr. C. G. Abbot.
David K. E. Bruce.
Ferdinand Lammot Belin.
Duncan Phillips.

FINANCE COMMITTEE

The Secretary of the Treasury, Henry Morgenthau, Jr.
The Secretary of State, Cordell Hull.
David K. E. Bruce.
Ferdinand Lammot Belin.
Samuel H. Kress.

ACQUISITIONS COMMITTEE

David K. E. Bruce.
Duncan Phillips.
Joseph E. Widener.
Ferdinand Lammot Belin.
David E. Finley.

During the year satisfactory progress has been made in the work of organizing the Gallery staff. All the positions required with few exceptions have now been classified by the Civil Service Commission, and examinations for several positions in the artistic

and professional field have been held by the Commission. The nuclear staff has been slightly increased so that it will be in a position to employ and train the staff which will be required when the building is completed and taken over by the Government. Twelve persons were employed on the Government roll as of June 30, 1940. This staff has been engaged in preparatory work and the compilation of the catalogs for the Gallery, and in the purchase of supplies and furniture to be placed in the Gallery building when completed, and in other matters looking toward the opening of the Gallery to the public. Until the Gallery is completed, the staff is being housed in offices furnished by The A. W. Mellon Educational and Charitable Trust.

A large part of the equipment, supplies, furniture, and furnishings have been purchased for delivery as soon as the building is completed. Favorable progress has been made upon the complete cataloging of the works of art in the national collections which will be housed in the Gallery building.

APPROPRIATIONS

For salaries and expenses, for the upkeep and operation of the National Gallery of Art, the protection and care of the works of art therein, and all administrative expenses incident thereto, as authorized by the act of March 24, 1937 (50 Stat. 51), as amended by the public resolution of April 13, 1939 (Pub. Res. No. 9, 76th Cong.), there was appropriated for the fiscal year 1941 the sum of $300,000. Of the sum of $159,000 appropriated by Congress for the period July 1, 1939, to June 30, 1940 (53 Stat. 984), $158,985.75 was expended or encumbered, in the following detailed amounts, for personal services, printing and binding, and supplies and equipment, leaving an unencumbered appropriation of $14.25.

Expenditures and encumbrances

Personal services	$21, 284. 63
Printing and binding	1, 901. 47
Supplies and equipment	135, 799. 65
Total	158, 985. 75

ACQUISITIONS

On February 12, 1940, the Board of Trustees accepted, from The A. W. Mellon Educational and Charitable Trust, a valuable gift of 11 celebrated paintings by early American artists which are considered outstanding not only for their aesthetic but also their historical merit. These paintings will be placed in specially designed rooms when the building is completed. This gift marks the first step toward setting up

in the National Gallery a section devoted to the advancement and preservation of American art. The gift includes the noted painting of the family of George Washington by Edward Savage. Other paintings given are as follows:

Painting	*Artist*
John Randolph	Gilbert Stuart.
Mrs. Richard Yates	Do.
Lawrence Yates	Do.
George Washington	Do.
Joseph Coolidge	Do.
Alexander Hamilton	John Trumbull.
William Vans Murray	Mather Brown.
Richard Earl Howe	John Copley.
Colonel Guy Johnson	Benjamin West.
John Randolph	Chester Harding.
A Young Man in a Large Hat	Frans Hals.
A Turk	Rembrandt.
Portrait of a Flemish Lady	Van Dyck.

At the same meeting the Board also accepted from Mr. Mellon's charitable trust two fountain groups by Pierre Legros and Jean Baptiste Tubi. These groups were executed in 1672 on orders of Louis XIV as a part of the decoration for the celebrated Theatre d'Eau at Versailles and are exceedingly valuable not only for their antiquity but for the quality of art they reflect. They are admirably suited for the settings arranged for them. One will be placed in each of the spacious garden courts which form an important architectural feature of the main floor of the Gallery.

During the year other offers of gifts of works of art were received but were not accepted because, in the opinion of the Board, they were not considered desirable acquisitions for the permanent collection of the Gallery as contemplated by section 5 (b) of the act of March 24, 1937.

EXCHANGE OF WORKS OF ART

On June 17, 1940, the duly authorized officers of the Gallery, as directed by the Board, on recommendations of the acquisitions committee, exchanged a terra-cotta bust representing Giovanna Tornabuoni and attributed to Verrocchio, in the Mellon collection, for the painting by Aelbert Cuyp entitled "The Maas at Dordrecht" and two monumental eighteenth century marble vases by Clodion (Claude Michel), all to be included in the permanent collection as more desirable and needed acquisitions for the Gallery. The two marble vases by Clodion are signed and dated 1782 and are said to have been made for the Palace of Versailles during the reign of Louis XVI. The painting by Cuyp is said by experts to be one of the greatest masterpieces of the work of that master of the Dutch school of the seventeenth century. The exchange had the approval of the donor.

RESTORATION AND REPAIRS TO WORKS OF ART

During the year, as authorized by the Board, Stephen Pichetto, Consultant Restorer to the Gallery, has undertaken such work of repair and restoration of paintings as has been found to be necessary, at his studio in New York. Such paintings when completed have been returned in excellent condition. Other necessary repairs and restoration to works of art in the collections will be done by Mr. Pichetto during the fiscal year ending June 30, 1941.

PAINTINGS LOANED AND RETURNED

During the year the following paintings from the Mellon collection were returned from the Masterpieces of Art Exhibition at the New York World's Fair where they had been on loan for the period April 30 to October 31, 1939, as reported by the Board of Trustees last year:

Painting	Artist
Self-Portrait	Rembrandt.
An Old Woman Seated	Hals.
A Gentleman Greeting a Lady	Terborch.

Also, the following paintings from the Mellon collection were returned from the Golden Gate International Exposition at San Francisco where they had been on loan for the period February 16 to December 31, 1939, as reported by the Board of Trustees last year:

Painting	Artist
A Young Man at Table	Rembrandt.
Portrait of Balthasar Coymans	Hals.
A Dutch Courtyard	Pieter de Hooch.

CURATORIAL WORK

Curatorial work during the year consisted primarily of studying and cataloging the large Mellon and Samuel H. Kress collections and in making recommendations for the installation of these collections in the Gallery building when it is completed.

PUBLICATIONS FUND

In its meeting of February 12, 1940, the Board adopted a resolution approving a plan for a publications fund. Carrying this plan into effect, a sum was advanced by The A. W. Mellon Educational and Charitable Trust to establish the Publications Fund, the purpose of which is to ensure that catalogs, handbooks, color reproductions, postcards, and similar material, of the highest quality but at moderate cost, shall be available to the public for educational and study purposes when the Gallery is opened. Considerable progress has already been made in the preparation of these publications.

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GALLERY CONSTRUCTION

Work on the Gallery building and landscaping on the site was started in the summer of 1937 and is rapidly nearing completion. It is hoped that construction will be completed in November of this year. Several months will be required for decorating the exhibition rooms and installing the collection. Formal opening of the Gallery to the public, therefore, may take place in March. As of June 30, 1940, $11,271,786.63 had been expended by The A. W. Mellon Educational and Charitable Trust for the construction of the building and landscaping of the site. It is estimated that the total construction cost of the building and landscaping will exceed $15,000,000. Upon advice of the accountants of the Gallery, recording of such costs on the books of the National Gallery of Art will be deferred until the building is turned over to the Smithsonian Institution and the trustees of the Gallery.

AUDIT OF PRIVATE FUNDS OF THE GALLERY

Price, Waterhouse & Co., a nationally known firm of public accountants, has made an examination of the accounting records maintained for the private funds of the National Gallery of Art and its Publications Fund for the year ended June 30, 1940. The certificate of Price, Waterhouse & Co. follows:

In accordance with instructions, we have made an examination of the accounting records maintained for the private funds of the National Gallery of Art and its Publications Fund for the year ending June 30, 1940, and have obtained information and explanations from its officers and employees. Records relating to the disbursement of public funds appropriated by Congress for the upkeep of the National Gallery of Art or the administrative expenses and cost of operation were not within the scope of our examination.

The recorded assets of the National Gallery of Art at June 30, 1940, comprised works of art donated by The A. W. Mellon Educational and Charitable Trust and by Mr. Samuel H. Kress and the Samuel H. Kress Foundation, or works of art acquired in exchange for donated items. The works of art acquired from The A. W. Mellon Educational and Charitable Trust were valued for accounting purposes at $31,892,502.31, including $589,340 for items acquired during the year under review. One piece of sculpture included in the first-mentioned amount at $185,000 was exchanged during the year for two vases and a painting appraised at values aggregating the same amount. The value for accounting purposes of the works of art donated June 29, 1939, by Mr. Samuel H. Kress and the Samuel H. Kress Foundation has not yet been determined. This gift is subject to completion of construction of the Gallery building on or before June 29, 1941, as provided in the gift indenture. The cost of construction of the building is being met by The A. W. Mellon Educational and Charitable Trust and the recording of the expenditures on the books of the National Gallery of Art is deferred until completion of the building.

The Publications Fund, National Gallery of Art was created by an indenture dated February 28, 1940 between The A. W. Mellon Educational and Charitable

Trust and three of the officers of the National Gallery of Art designated as "Custodians." The Fund was established for the purpose of making available to the public, at reasonable cost, catalogues and other publications concerning the works of art. The Trust advanced to the Custodians the sum of $40,000, and the indenture provides for repayment after July 1, 1941, out of profits, if any, from sale of publications and for transfer of any remaining assets of the Fund to the National Gallery of Art after the advance has been entirely paid. We obtained a confirmation from the National Metropolitan Bank of the amount of $40,000 on deposit at June 30, 1940.

Our examination disclosed no other transactions to June 30, 1940, which should be recorded in the books of account. We did not inspect the works of art but we examined the deeds of trust which provide that the donors shall be responsible for the custody and shall bear the cost of storage and insurance until the delivery of the works of art after completion of the Gallery building.

In our opinion, subject to the fact that the value of the works of art acquired June 29, 1939, has not been determined and recorded, the books of account fairly reflect the transactions pertaining to the private funds of the National Gallery of Art and of the Publications Fund, National Gallery of Art, at June 30, 1940, in conformity with generally accepted accounting principles applied on a basis consistent with that of the preceding year.

Respectfully submitted.

F. L. Belin, *Vice President.*

Dr. C. G. Abbot,
Secretary, Smithsonian Institution.

APPENDIX 3

REPORT ON THE NATIONAL COLLECTION OF FINE ARTS

SIR: I have the honor to submit the following report on the activities of the National Collection of Fine Arts for the fiscal year ended June 30, 1940:

The beginning of the year found the Gallery in the throes of major repairs which continued for several months after the first of July. The galleries were reopened to the public October 4, 1939. A new background of rubber-backed monk's cloth was used, with all trimmings, baseboards, railings, and reflectors painted to match. This produces such a soft, quiet effect that all attention is centered on the exhibits themselves. The pictures were all put in first-class condition and backed.

Five special exhibits were held in the foyer, and two, of miniatures, in the Gallery proper. The Smithsonian Building, where Graphic Arts exhibits have usually been held, was closed to the public on account of alterations, so that the nine such exhibits held during the year were transferred to the north lobby of the Natural History Building and were displayed in National Collection of Fine Arts cases.

Three miniatures were purchased and two others were received as loans. Loans of large objects or paintings cannot be accepted because of crowded conditions in the galleries and in storage.

APPROPRIATIONS

For the administration of the National Collection of Fine Arts by the Smithsonian Institution, including compensation of necessary employees, purchase of books of reference and periodicals, traveling expenses, uniforms for guards, and necessary incidental expenses, $33,765 was appropriated, of which $11,999.89 was expended for the care and maintenance of the Freer Gallery of Art, a unit of the National Collection of Fine Arts. The balance of $21,765.11 was spent for the care and upkeep of the National Collection of Fine Arts, nearly all of this sum being required for the payment of salaries, traveling expenses, books, periodicals, and necessary disbursements for the care of the collection.

THE SMITHSONIAN ART COMMISSION

The nineteenth annual meeting of the Smithsonian Art Commission was held on December 5, 1939. The members met at 10:30 in the Natural History Building, where, as the advisory committee on the acceptance of works of art which had been submitted during the year, they accepted the following:

Oil painting "Young Girl with Dog," by Edward Percy Moran, 1890 (1862–1925). Bequest of Alfred Duane Pell.

Mr. McClellan and Mr. Lodge were appointed to select objects from the 207 ceramics, 106 ivory carvings, 30 fans, 5 pieces of silver, 3 tapestries, and 3 chairs, received from the bequest of Alfred Duane Pell, which they considered suitable for the National Collection of Fine Arts.

After a brief visit to the Freer Gallery of Art, the members proceeded to the regent's room in the Smithsonian Building for the further proceedings, the meeting being called to order by the chairman, Mr. Borie.

The members present were: Charles L. Borie, Jr., chairman; Frank Jewett Mather, Jr., vice chairman; Dr. Charles G. Abbot (ex officio), secretary; and Louis Ayres, David E. Finley, John E. Lodge, Paul Manship, George B. McClellan, Edward W. Redfield, and Mahonri M. Young. Ruel P. Tolman, Curator of the Division of Graphic Arts in the United States National Museum and Acting Director of the National Collection of Fine Arts, was also present.

The Commission recommended to the Board of Regents the reelection of Louis Ayres, James E. Fraser, George H. Edgell, and Frank Jewett Mather, Jr.

The following officers were reelected for the ensuing year: Charles L. Borie, Jr., chairman; Frank Jewett Mather, Jr., vice chairman, and Dr. Charles G. Abbot, secretary.

The following were reelected members of the executive committee for the ensuing year: George B. McClellan (chairman), Herbert Adams, and Gilmore D. Clarke. Charles L. Borie, Jr., as chairman of the Commission, and Dr. Charles G. Abbot, as secretary of the Commission, are ex-officio members of the executive committee.

Dr. Abbot reported in detail regarding various phases of the act providing for the Smithsonian Gallery of Art; of the rules under which the recent competition for a design for the Gallery had been carried out; of the results of the competition; and of the suitability of the prize-winning design. After a very full discussion by the Commission, during which Dr. Abbot stated that he would be glad to submit to the forthcoming meeting of the Board of Regents any

expression of opinion which the Commission might agree upon, Mr. Mather submitted the following resolution which the members present, on motion, adopted as their opinion in the matter:

The primary purpose of the Smithsonian Gallery of Art is worthily to house, classify, and exhibit such art collections as the Smithsonian Institution now has or shall have. The secondary purpose is to make an educational use of such art collections through direct instruction at Washington or through loan exhibitions in the United States or elsewhere.

THE CATHERINE WALDEN MYER FUND

Three miniatures were acquired from the fund established through the bequest of the late Catherine Walden Myer, as follows:

19. "Portrait of I. G.," by an unknown artist; from John Schwarz, Baltimore, Md.

20. "Portrait of a Colonial Gentleman," signed Copley, 1773; from Whitlock's Incorporated, New Haven, Conn.

21. "Portrait of a Man," by an unknown artist; from Michael J. de Sherbinin, Mount Vernon, N. Y.

LOANS ACCEPTED

A miniature of Mrs. Robert Means, by Edward Greene Malbone (1777–1807) was lent by J. J. Pringle, Jr., Alexandria, Va.

A miniature of Ebenezer Martin (1791–1876) by an unknown artist, was lent by Miss Alice L. Wood, Blowing Rock, N. C.

A portrait of Mr. Justice Brandeis, by Joseph Tepper, was lent by the friends of Mr. Justice Brandeis, through Paul A. Freund, Harvard University, Cambridge, Mass.

Three paintings—"Portrait of Woman in White," by Haggenaes, "Linlithgan Bridge," by Macaulay Stevenson, and "Landscape—Moonlight," by E. R. Menard—were lent by Miss A. M. Hegeman, Washington, D. C.

LOANS TO OTHER MUSEUMS AND ORGANIZATIONS

An oil painting, "Brittany Sunday," by Eugene Vail, was lent to the Corcoran Gallery of Art for a memorial exhibition from January 6 to 28, 1940. (Returned February 1, 1940.)

Two oil paintings, "Portrait of Stephen Decatur," by Gilbert Stuart, and "Portrait of Admiral Sims," by Irving R. Wiles, were lent to the United States Naval Academy for an exhibition of Masterpieces of Painting and Graphic Arts relating to Naval Personages and Traditions from April 6 to May 15, 1940. (Returned May 20, 1940.)

The following four paintings were lent in April 1940 to The Public Library of the District of Columbia:

"Portrait of Thomas McKean," by Charles Willson Peale, and "Portrait of Mary Abigail Willing Coale," by Thomas Sully, to the Georgetown Branch.

"Madonna with Halo of Stars," by an unknown artist, to the Southeastern Branch.

"Musa Regina," by Henry Oliver Walker, to the Northeastern Branch.

An oil painting, "Portrait of Mary Hopkinson (wife of Dr. John Morgan)," by Benjamin West, was lent May 20, 1940, to the Masterpieces of Art exhibition at the New York World's Fair, 1940.

Two oil paintings, "The Torrent" and "Fishing Boats at Gloucester," by John Twachtman, were lent to the Munson-Williams-Proctor Institute, Utica, N. Y., for an exhibition of the work of John Twachtman from November 5 to 28, 1939. (Returned December 1, 1939.)

An oil painting, "Moonlight," by Albert P. Ryder, was lent to M. Knoedler & Co., New York City, for an exhibition of paintings by Albert P. Ryder and Robert L. Newman called "Two American Romantics" from November 13 to December 2, 1939. (Returned December 6, 1939.)

Two oil paintings, "Caresse Enfantine," by Mary Cassatt, and "Sunset, Navarro Ridge, California Coast," by Ralph A. Blakelock, were lent to the Art Institute of Chicago for an exhibition, "Half a Century of American Art (1888–1939)," from November 16, 1939, to January 7, 1940. The Blakelock painting was forwarded to Chicago at the close of the Golden Gate International Exposition, San Francisco, Calif. (Returned January 10, 1940.)

LOANS RETURNED

The painting "Friendly Neighbors," by Alfred C. Howland, lent to Harvard University, William Hayes Fogg Art Museum, Cambridge, Mass., for an exhibition of New England genre by New England artists, was returned September 8, 1939.

THE NATIONAL COLLECTION OF FINE ARTS REFERENCE LIBRARY

A total of 471 publications, including 334 acquired by purchase and 2 by transfer, were accessioned during the year.

OTHER ACTIVITIES

The Acting Director visited and studied collections and methods of installation in New England galleries from August 21 to September 1, 1939.

Four colored lantern slides were lent to Holbrook Muller for use in connection with a lecture given at the Washington Heights Presbyterian Church, December 26, 1939.

SPECIAL EXHIBITIONS

The following exhibitions were held:

November 9 to 29, 1939.—The Fifth Annual Metropolitan State Art Contest, 1939, under the auspices of the Department of Fine Arts of the District of Columbia Federation of Women's Clubs. There were 272 exhibits, paintings, sculpture, and prints, by 128 artists.

December 12, 1939, to January 1, 1940.—Special exhibition of 29 pastel and oil paintings by Esteban Valderrama, under the patronage of His Excellency the Ambassador of Cuba, Señor Dr. Pedro Martinez Fraga.

December 15, 1939, to February 8, 1940.—Special exhibition of a miniature by Juan de Dios Hoyos, under the patronage of His Excellency the Ambassador of Mexico, Señor Dr. Francisco Castillo Najera.

January 9 to 25, 1940.—Special exhibition of 83 pieces of wood turnings by James L. Prestini of Lake Forest, Ill.

January 9 to 31, 1940.—Special exhibition of 24 portraits and 5 drawings by John Slavin, of Richmond, Va.

April 4 to 28, 1940.—Special exhibition of 153 paintings by 31 members of the Landscape Club of Washington, D. C.

May 25 to June 10, 1940.—Special exhibition of 103 miniatures by 61 members of the Pennsylvania Society of Miniature Painters.

PUBLICATIONS

TOLMAN, R. P. Report on the National Collection of Fine Arts for the year ended June 30, 1939. Appendix 3, Report of the Secretary of the Smithsonian Institution for the year ended June 30, 1939, pp. 47–51.

LODGE, J. E. Report on the Freer Gallery of Art for the year ended June 30, 1939. Appendix 4, Report of the Secretary of the Smithsonian Institution for the year ended June 30, 1939, pp. 52–55.

Respectfully submitted.

R. P. TOLMAN, *Acting Director.*

Dr. C. G. ABBOT,
Secretary, Smithsonian Institution.

APPENDIX 4

REPORT ON THE FREER GALLERY OF ART

SIR: I have the honor to submit the twentieth annual report on the Freer Gallery of Art for the year ended June 30, 1940:

THE COLLECTIONS

Additions to the collections by purchase are as follows:

BAMBOO

39.78–
39.79. Chinese, seventeenth–eighteenth century. By Chang Shih-huang. Two brush-holders with landscape designs, inscriptions and signatures carved in delicate relief. Heights: 0.122 and 0.106 respectively.

BRONZE

39.38. Chinese, Eastern Han dynasty, dated in correspondence with A. D. 174. A mirror. Smooth black patina; decoration and inscription in countersunk relief. Diameter: 0.182.

39.39–
39.40. Chinese, late Shang dynasty, fourteenth–twelfth century B. C. Two ceremonial weapons of the type *kê*, each ornamented on both sides with turquoise inlay. Rough green patina. Lengths: 0.393 and 0.391, respectively.

39.41. Chinese, late Chou dynasty, fifth–third century B. C. A ceremonial vessel of the type *tou*. Granular, bluish green patination; design inlaid with gold. 0.151 x 0.189 over all.

39.52. Chinese, Western Chin dynasty, third century A. D. A mirror. White bronze patinated in black, gray, and green with earthy encrustations. On the back, concentric zones of mythological and legendary subjects in high and countersunk relief. A dedicatory inscription of 43 characters. Diameter: 0.175.

39.53. Chinese, early Chou dynasty or earlier, twelfth century B. C. A ceremonial vessel of the type *kuang*. White bronze with smooth light gray-green patina. Decoration in linear relief. 0.169 x 0.196 over all. (Illustrated.)

40.3. Chinese, late Shang dynasty, fourteenth–twelfth century B. C. A vase of the type *ku*. White bronze with a green and black patina. Decoration in linear relief. Inscription. 0.284 x 0.157 over all.

BRONZE AND JADE

40.10. Chinese, late Shang dynasty, fourteenth–twelfth century B. C. Probably from An-yang. A ceremonial sickle in four parts: three of bronze inlaid with turquoise; one (the blade) of jade decorated in linear relief with notched back and ground edge. 0.345 x 0.175 over all (when assembled with all parts in contact). (Illustrated.)

JADE

39.54. Chinese, middle Chou dynasty, eighth–fifth century B. C. An oblong ornament of reddish color shading to gray-green; somewhat translucent; decoration in linear relief. 0.073 x 0.033 over all.

39.55. Chinese, early Chou dynasty, twelfth–eighth century B. C. A ceremonial "toothed" blade of a yellow-brown color with cloudy mottlings of darker brown. 0.411 x 0.065 over all.

MANUSCRIPT

(See also Painting, 39.49b and 39.50b)

39.43. East Indian, fifteenth century. Part of a Jaina *sūtra:* nine leaves of thin paper between brocade-covered boards. Two miniatures. (See under Painting, 39.43.) 0.074 x 0.253 (average leaf).

39.56. Arabic (Persia), Seljuq period, eleventh–twelfth century. A leaf from a *Qur'ān.* The text is written in slender Kufic script in black ink on a ground filled with palmette scrolls drawn in brown ink; vowel-signs in red, blue, and brown. Gold verse-stops, borders, and marginal ornaments. 0.323 x 0.214.

MARBLE

40.2. Chinese, late Shang dynasty, fourteenth–twelfth century B. C. A terminal ornament in the form of a bird; surface details in linear relief on both sides. 0.121 x 0.070 over all.

METAL WORK

39.44 a–b. Iranian (Persian) late eighteenth century. A dagger and sheath, probably made in Shirāz. Curved, double-edged blade of steel. Hilt and scabbard of iron ornamented with gold inlay; arabesques and inscriptions in relief. Length: 0.372.

39.45. Iranian (Persian) sixteenth century. A pierced steel rectangular plaque, a portion of a frieze, containing two medallions with *naskhī* inscriptions on a ground of tendril scrollwork. 0.077 x 0.269.

39.58. Syro-Egyptian, sixteenth century. A globular brass hand-warmer made in two hemispheres, one fitted with a fire pot hung in gimbals. The surface is pierced with small holes; the decoration engraved and inlaid with silver. Diameter: 0.125.

40.4–40.9. Iranian (Persian) sixteenth–seventeenth century. Six small objects of iron and steel:

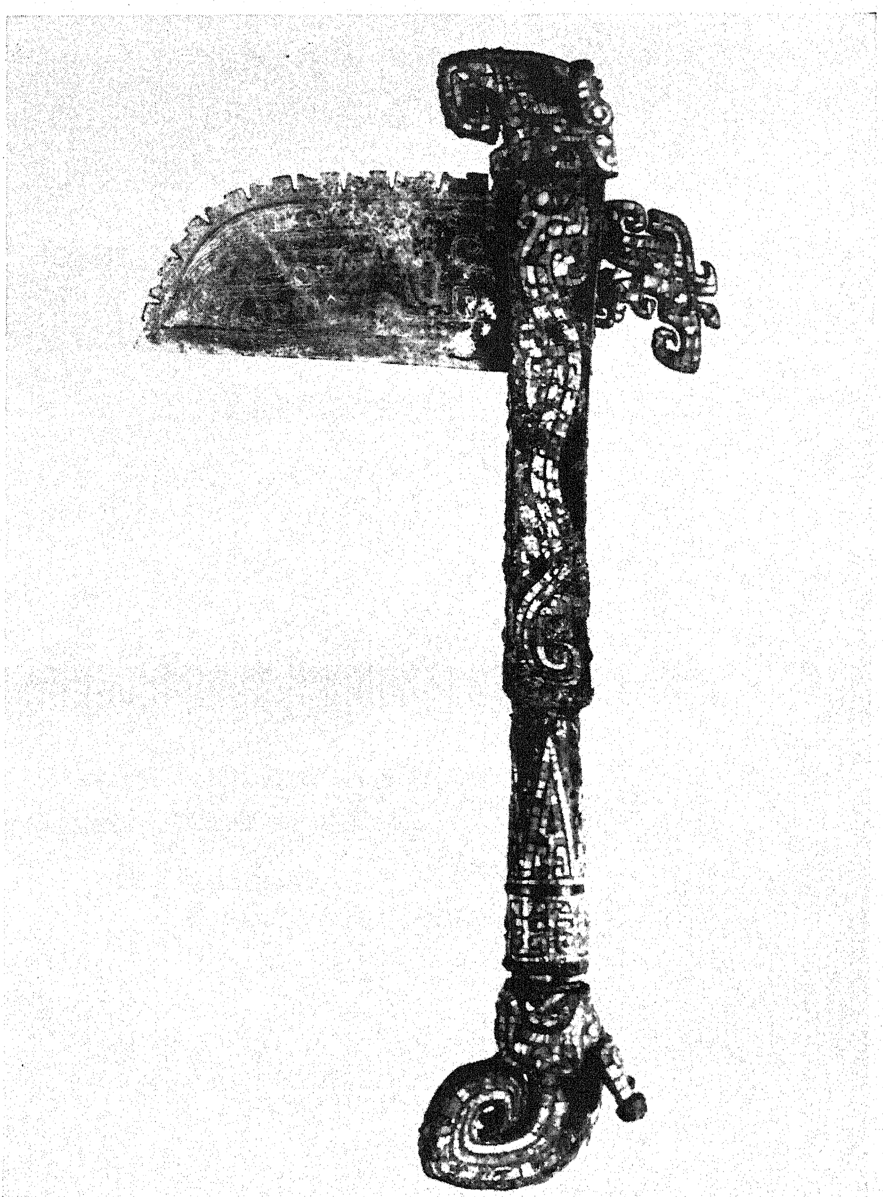
40.4–40.5. Two sheet-iron comb-backs with sockets for teeth. The decoration is engraved and inlaid with silver and gold. 0.062 x 0.077 and 0.061 x 0.109, respectively.

40.6. A steel hatchet (or chopper) head with screwpin and nut for shafting. Decoration pierced and engraved. 0.159 x 0.078 over all.

40.7. A steel flint-striker in the form of a bird; the decoration is engraved and inlaid with gold; jewels (one damaged) set in the eyes. 0.087 x 0.050 over all.

40.8. A rectangular steel ornament of interlacing vine-scrolls in delicate pierced work. 0.038 x 0.071 over all.

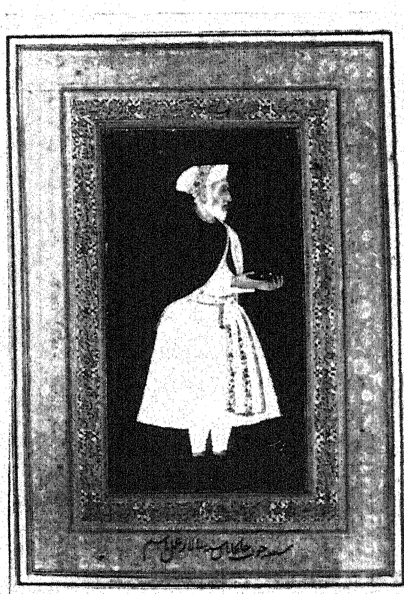
40.9. A circular steel ornament: pierced work with the *bismallah* in gold on a ground of tendrils; gold border. Diameter: 0.046.



40.10

A RECENT ADDITION TO THE COLLECTION OF THE FREER GALLERY OF ART.

39.53



39.50a

39.48b

SOME RECENT ADDITIONS TO THE COLLECTION OF THE FREER GALLERY OF ART.

PAINTING

39.37. Chinese, Sung dynasty or earlier. Style of Chou Fang. "Ladies playing double-sixes." Color on silk. Title, one other inscription, and 3 seals on the mount. Makimono: 0.307 x 0.480.

39.51. Chinese, Ming dynasty, dated in correspondence with A. D. 1536. By Wên Pi (Chêng-ming, 1470–1567). A landscape. Ink on paper. Inscription and 16 seals on the picture; 2 inscriptions and 2 seals on the mount. Makimono: 0.314 x 2.903.

39.59. Chinese, Yüan dynasty, fourteenth century. By Wang Mêng (died 1385). A landscape. Ink and color on paper. One inscription and 10 seals on the picture; label, 4 inscriptions and 25 seals on the mount. Makimono: 0.245 x 0.972.

39.60. Chinese, Ming dynasty, fifteenth–sixteenth century. By T'ang Yin (1466–1524). Landscape. Ink and color on paper. One inscription and 5 seals on the picture; label, 9 inscriptions and 28 seals on the mount. Makimono: 0.283 x 1.030.

40.1. Chinese, Yüan dynasty, fourteenth century. Attribution to Chao Lin. Tatar horsemen. Ink and gold on paper. Two inscriptions and 7 seals on the picture; label on the mount. Makimono: 1.083 x 0.238.

39.43. Indian, fifteenth century. Two miniatures illustrating part of a Jaina *sūtra* (see also Manuscript, 39.43). Color and metallic lustre on paper: Leaf 1: A deity enthroned; two worshippers. Leaf 3: A deity enthroned; six other figures. 0.074 x 0.058 and 0.073 x 0.058, respectively.

39.46a–
39.50b. Indian, Mughal, seventeenth century. Five leaves from a royal album upon which are mounted eight paintings on paper and two pages of Persian calligraphy (*qiṭa'*):

39.46a. School of Shāh Jahān. By Govardhan. An equestrian portrait of the Emperor Shāh Jahān. Color and gold. Signature. 0.268 x 0.181.

39.46b. School of Jahāngīr. By Manṣūr. A bird. Color. Signature. 0.114 x 0.205.

39.47a. School of Jahāngīr. Dated in correspondence with A. D. 1620. Attribution to Farrukh Beg. Shāh Ṭahmāsp in the mountains. Color and gold. Inscription. 0.219 x 0.138.

39.47b. School of Jahāngīr. By Muḥammad. A bird. Color and gold. Inscription. 0.142 x 0.100.

39.48a. School of Jahāngīr. Attribution to Manṣūr. Two deer in a landscape. Color and gold. Inscription. 0.167 x 0.093.

39.48b. School of Jahāngīr. Dated in correspondence with A. D. 1610. The Emperor Humāyūn enthroned, a sword bearer in attendance. Color and gold. Inscription. 0.181 x 0.119. (Illustrated.)

39.49a. School of Shāh Jahān. Dated in correspondence with A. D. 1629. By Hāshim. The Emperor Shāh Jahān standing upon a globe; above, angels in clouds bearing insignia of sovereignty. Color and gold; faint outline drawings on the globe. Signature and inscriptions. 0.251 x 0.158.

39.49b. Persian, sixteenth century. By Mīr 'Alī. An illuminated *qiṭa'*. *Nasta'līq* script on blue paper. Signature. 0.171 x 0.092.

39.50a. School of Jahāngīr, *ca.* A. D. 1625. By Hāshim. A portrait of the Khān-Khānān ('Abd-'r-Raḥīm). Color and gold. Signature. 0.149 x 0.082. (Illustrated).

39.50b. Persian, sixteenth century. By Mīr 'Alī. An illuminated *qiṭa'*. *Nasta'līq* script on blue paper. Signature. 0.186 x 0.087.

POTTERY

39.42. Chinese, late Shang dynasty, fourteenth-twelfth century B. C. From An-yang. A jar (mouth chipped and repaired) of soft, white, unglazed clay. The decoration is carved in countersunk relief in two registers. Three pierced knobs of water-buffalo design. 0.332 x 0.305 over all.

39.61–
39.77. Chinese, Ming to Ch'ing dynasties, sixteenth-nineteenth (?) century. I-hsing pottery. Seventeen objects of brown, red, or gray polished, unglazed clay:

39.61. Tea-pot, sixteenth century (?) Attribution to Kung Ch'un.
39.62. Tea-pot, seventeenth century. By Shih Ta-pin.
39.63. Tea-pot, seventeenth century. By Shih Ta-pin.
39.64. Tea-pot, dated in correspondence with A. D. 1620. By Li Chung-fang.
39.65. Tea-pot, seventeenth century. By Hsü Yu-ch'üan.
39.66. Tea-pot, seventeenth century. By Ch'ên Ch'ên (styled Kung-chih).
39.67. Tea-pot, dated in correspondence with A. D. 1642. By Shên Tzŭ-ch'ê.
39.68. Tea-pot, sixteenth-seventeenth century. By Ch'ên Ming-yüan.
39.69. Tea-pot, sixteenth-seventeenth century. By Ch'ên Ming-yüan.
39.70. Tea-pot, eighteenth century. By Ch'ên Han-wên.
39.71. Water-pot, sixteenth-seventeenth century. By Ch'ên Ming-yüan.
39.72. Water-pot, sixteenth-seventeenth century. By Ch'ên Ming-yüan.
39.73. Incense-box, sixteenth-seventeenth century. By Ch'ên Ming-yüan.
39.74. Brush-rest, sixteenth-seventeenth century. By Ch'ên Ming-yüan.
39.75. Oval cup, nineteenth century (?). By Ch'êng-chai.
39.76. Octagonal cup, nineteenth century (?). By Ch'êng-chai.
39.77. Fluted cup, nineteenth century (?). By Ch'êng-chai.

Curatorial work has been devoted to the study and recording of the new acquisitions listed above, and to other Chinese, Arabic, Persian, East Indian, Aramaic, and Armenian manuscripts or art objects either already in the permanent collection or submitted for purchase. Other Chinese, Japanese, Arabic, Persian, Egyptian, American, and European objects were sent or brought to the Director by their owners for information as to identity, provenance, quality, date, inscriptions, and so on. In all, 1,093 objects and 263 photographs of objects were so submitted, and written or oral reports upon them were made to the institutions or private owners requesting this service. Written translations of 21 inscriptions in Oriental languages also were made upon request.

Forty changes were made in exhibition as follows:

Chinese bronze	21
Chinese painting	7
East Indian painting	12

ATTENDANCE

The Gallery has been open to the public every day from 9 until 4:30 o'clock, with the exception of Mondays, Christmas Day, and New Year's Day.

The total attendance of visitors coming in at the main entrance was 108,638. One hundred and thirty-two other visitors on Mondays make the grand total 108,770. The total attendance for week days, exclusive of Mondays, was 77,129; Sundays, 31,509. The average week-day attendance was 297; the average Sunday attendance, 606. The highest monthly attendance was, as usual, in April, 18,736; the lowest in January, 4,351.

There were 1,577 visitors to the main office during the year. The purposes of their visits were as follows:

For general information	327
To see objects in storage	419
Far Eastern paintings	98
Near Eastern paintings and manuscripts	25
East Indian paintings and manuscripts	10
American paintings	36
Whistler prints	9
Oriental pottery, jade, lacquer, bronzes, and sculptures	165
Syrian, Arabic, and Egyptian glass	3
Byzantine objects	3
Washington Manuscripts	70
To read in the library	215
To make tracings and sketches from library books	4
To see the building and installation	15
To obtain permission to photograph or sketch	24
To submit objects for examination	176
To see members of the staff	151
To see the exhibition galleries on Mondays	42
To examine or purchase photographs	457

Of the 1,577 visitors to the offices, 132 came in on Mondays.

LECTURES, DOCENT SERVICE, AND AUDITORIUM

Eight illustrated lectures were given by members of the staff in the auditorium: total attendance, 197. Upon request, 11 groups ranging from 7 to 20 persons (total, 145) were given instruction in the study rooms, and 7 groups ranging from 5 to 24 persons (total, 114) were given docent service in the exhibition galleries. The total number of persons receiving instruction at their own request was 456.

The auditorium has been used by the following groups:

Bureau of Agricultural Economics of the U. S. Department of Agriculture: 4 meetings; total attendance, 1,200.

Federal Crop Insurance Corporation of the U. S. Department of Agriculture: 4 meetings; total attendance, 729.

Eighth American Scientific Congress: 1 meeting; attendance, 15.

PERSONNEL

William R. B. Acker, Student Assistant, left for Holland on July 3, 1939, to pursue his Chinese studies at the University of Leiden.

On August 18, 1939, the Gallery suffered a great loss in the death of its Superintendent, John Bundy, at his home in Ridgewood, N. J. Mr. Bundy had been associated with the Freer building for more than 21 years, coming here first as the representative of the architect, Charles A. Platt, of New York. During 1921 he was transferred to the staff of the Freer Gallery as Superintendent, a post he held until his death. To his work he brought not only the highest degree of technical proficiency, the fruit of long experience, but also the single-minded devotion of a strong and loyal character.

Weldon N. Rawley, who has been associated with the Gallery since December 1, 1921, was appointed Superintendent on September 20, 1939.

On March 22, 1940, Eleanor Thompson Snedeker resigned as assistant, a position she had held since November 15, 1929. On the same day the appointment of Margaret B. Arnold to succeed Mrs. Snedeker became effective.

March 28, 1940, Emil L. Zorn reported for duty as senior cabinetmaker.

Grace T. Whitney worked intermittently at the Gallery between October 9, 1939, and June 24, 1940, upon translations of Persian texts.

Respectfully submitted.

J. E. Lodge, *Director*

Dr. C. G. Abbot,
Secretary, Smithsonian Institution.

APPENDIX 5

REPORT ON THE BUREAU OF AMERICAN ETHNOLOGY

SIR: I have the honor to submit the following report on the field researches, office work, and other operations of the Bureau of American Ethnology during the fiscal year ended June 30, 1940, conducted in accordance with the act of Congress of March 16, 1939, which provides "* * * for continuing ethnological researches among the American Indians and the natives of Hawaii and the excavation and preservation of archeologic remains. * * *"

SYSTEMATIC RESEARCHES

M. W. Stirling, Chief of the Bureau, left Washington on December 26 to continue his archeological excavations in southeastern Mexico. Work was continued at Tres Zapotes until April 20. Two additional expeditions were made, one to Cerro de Mesa on the Rio Blanco in the State of Veracruz, and the other to La Venta in northern Tabasco. As last year, the work was undertaken in cooperation with the National Geographic Society. Dr. Philip Drucker accompanied Mr. Stirling as assistant archeologist.

As a result of the second season of work, the chronology of the Tres Zapotes site has now been satisfactorily determined. Indications are that the site was occupied from a date before the beginning of the Christian era but that it was abandoned sometime before the beginning of the Spanish conquest.

At Cerro de Mesa, 20 carved stone monuments were located and photographed, including one with an initial series date in the Maya calendar. This date reads 9–1–12–14–10, or 1 Oc 3 Uyab. The discovery of this monument raises to three the number of initial series now known from the State of Veracruz. Although a very early Baktun 9 date, it is later than Stela C from Tres Zapotes and the Tuxtla statuette. Of the 20 monuments at Cerro de Mesa, 12 are stelae.

Twenty monuments were also unearthed at La Venta, including five colossal heads, several beautifully carved altars, and some stelae.

At the conclusion of the work the collections were brought to Mexico City and a division of the material was made by the department of archeology of the Mexican Government, whose splendid cooperation did much to facilitate the work in the field.

Mr. Stirling attended three anthropological conferences as a delegate of the United States Government, these being the Twenty-seventh Session, International Congress of Americanists, held at Mexico City, August 5–15, 1939; the First Inter-American Congress on Indian Life, at Patzcuaro, Michoacán, April 14–24, 1940; and the Eighth American Scientific Congress, in Washington, May 10–21, 1940.

Dr. J. R. Swanton, ethnologist, devoted the greater part of the fiscal year to the assembling of material bearing on the ethnology and early history of the Caddo Indians, former inhabitants of northwestern Louisiana, southwestern Arkansas, northeastern Texas, and southeastern Oklahoma. This now covers about 700 typewritten pages including copies of original Spanish and French texts. He rendered assistance to various local organizations in preparing for the placing of markers along the trail followed by Hernando de Soto and celebrations connected with them. Investigations were undertaken for the United States Board on Geographical Names, of which Dr. Swanton is a member. A bulletin by him entitled "Linguistic Material From the Tribes of Southern Texas and Northeastern Mexico" is now in page proof.

Dr. Swanton was much gratified at the kind recognition tendered by his anthropological associates this year on the completion of 40 years' service in the Bureau and the Institution in having dedicated to him volume 100 of the Smithsonian Miscellaneous Collections entitled "Essays in Historical Anthropology of North America."

At the beginning of the fiscal year, Dr. John P. Harrington, ethnologist, was engaged in field studies at Anadarko and Apache, Okla., on the Kiowa Apache Tribe, in reality a variety of Lipan and not Apache Indians according to language, and possibly identical with the "Palomas" of early Spanish archives of New Mexico. These peoples, which can well be termed "Lipanan" from the Lipan, one of the tribes, have become extinct or have been shoved far from their former ranges, with the sole exception of the Kiowa Apache, which, because of alliance with the powerful Kiowa Tribe, succeeded in remaining in the region although assimilating the Kiowa culture.

Returning to Washington, Dr. Harrington proceeded in the latter part of July to Window Rock, Ariz., location of the administrative headquarters of the Navaho Tribe. Just as the Kiowa Apache show a subtype of western Plains culture submerged to that of the Kiowa, so the Navaho show Great Basin culture with a varnish of many Pueblo features, and study proves that these Pueblo features are in every case directly derived from some particular Pueblo

with which the Navaho have had century-long contact. For instance, the Navaho of Ramah derive their Pueblo features from Zuñi. The most interesting discovery of all was the prominence of the buffalo in Navaho ceremony, in which the buffalo plays a role as large as among the Pueblos.

In the case of both the Kiowa Apache and Navaho, language study is the most practical means of proving that the language-bearing ancestors of these tribes came from the north, where similar languages are still spoken, occupying the interior of Alaska and of western Canada.

Proceeding October 25 to the Chipewyan of eastern Alberta, Canada, Dr. Harrington found them to consist of a southern-projecting tongue of the language of the great Athabaska Lake of northern Alberta, which derives its name from Algonquian Cree Adhapaskaaw, meaning "much grass" and applied originally to the Peace River Delta at the western end of the lake. Chipewyan means "pointed skins," referring to an old habit of dress. The Chipewyan language proved to be surprisingly close to Navaho in vocabulary and construction.

Proceeding to the Sarcee language of southern Alberta, Dr. Harrington encountered another closely related tongue, and one which is most nearly affiliated with the Beaver and the Sekeneh, two dialects that lie north of the Sarcee. Dr. Harrington learned the tradition that the Sarcee and Beaver were originally one people but that in migrating southward across a frozen lake, the water monster became angered and broke the ice, those Indians on the northern side becoming the Beaver and those having crossed to the southern side becoming the Sarcee. The Sarcee were found to have adopted the culture of the neighboring Blackfeet, and the meaning of the name of the Blackfeet, Ayaatciyiiniw, was found to be "ugly enemy."

The Carrier, Chilcotin, and Nicola dialects were reached in December. These are located on the upper Fraser River, especially about the great lakes at the head of this stream.

The Sekeneh were also reached in British Columbia and the name was found to mean "Rocky Mountain Indian."

Returning to Washington, Dr. Harrington proceeded in March to the study of the Tlinkit Indians of southeastern Alaska, finding these to be related to the Navaho, in a close relationship which cannot mean many centuries of separation.

Dr. Harrington then proceeded in May to the study of the Atchat, or Eyak, Tribe, which was found to have occupied the entire eastern half of the Gulf of Alaska, a stretch of coast 350 miles long, extending from Prince William Sound in the west to Latuya Bay in the east. This tribe has earlier been called Ugalenz and Eyak, but the real

name of the tribe has never been known, Atchat meaning "on this side" or "opposite," referring to location on the Gulf of Alaska and opposite the islands. This language also proved to be closely related to the Navaho, and, as might be expected, more closely related to the languages of British Columbia and the Navaho than is the island language.

Dr. Harrington returned to Washington on June 29.

At the beginning of the fiscal year, July 1, Dr. Frank H. H. Roberts, Jr., archeologist, was engaged in excavating at the Lindenmeier site in northern Colorado. The investigations were continued through July and August and were brought to a close for the season on September 15. The area under examination was a portion of the Folsom camp site that has occupied a Bureau of American Ethnology-Smithsonian Institution Expedition's attention for several seasons. The 1939 excavations consisted of the removal of the overburden, ranging from 3½ to 5½ feet in thickness, from some 1,540 square feet of the old area of occupation, digging a series of 10 test trenches in unsampled parts of the site, and prospecting in outcroppings of the archeological layer in the banks of a deep ravine that traverses a portion of the site. The excavations in the camp remains produced more specimens than any previously made in areas of comparable size. The collection of artifacts includes typically fluted Folsom points, fluted knives, knives made from the flakes removed from the faces of the points in producing the channels, other kinds of flake knives, a variety of scrapers including several forms of the spokeshave type, flakes with small points used for marking on bone and wood, handhammer stones and large choppers, red and yellow ochers used for pigments, bone punches and awls, pieces of decorated bone from objects of unknown form and function, and tubular bone beads. The latter are the first to be found in the Folsom Complex. They were made from shafts of long bones. Unfortunately, the criteria for identification were removed in the process of manufacture, but they seem to be rabbit and bird. One of these specimens was decorated with a series of short parallel lines cut into its surface.

Dr. Roberts returned to the office in Washington on October 1. During the fall and winter months he read galley and page proofs on the report Archeological Remains in the Whitewater District, Eastern Arizona. Part II. Artifacts and Burials, which appeared as Bulletin 126 of the Bureau of American Ethnology. He also served as technical advisor for "The World is Yours" programs, "Cortez, the Conquistador" and "Pompeii Lives Again," and wrote the article for "The World is Yours" pamphlet on Pompeii. He also prepared a manuscript on the subject Developments in the Problem of the North American Paleo-Indian. Galley and page proofs were

read and corrected for this paper, which appeared in the Essays in Historical Anthropology of North America, volume 100, Smithsonian Miscellaneous Collections. Special papers on archeological subjects were prepared and presented before the Pennsylvania State Archeological Society, the American Anthropological Association, and the Eighth American Scientific Congress.

Dr. Roberts left Washington, May 26, for Colorado and resumed investigations at the Lindenmeier site. While the preliminary excavations were under way, a number of places in that vicinity were visited for the purpose of checking purported finds of Folsom material. Work at the Lindenmeier site was in full progress at the close of the fiscal year.

As editor of the Handbook of South American Indians, Dr. Julian H. Steward, anthropologist, in consultation with leading authorities on South American anthropology, drew up a working outline for this project. A two-volume, 2,000-page work to be published in 5 years, the Handbook will contain articles by specialists on the various subjects. The volume of essays in honor of Dr. Swanton, for which Dr. Steward served as technical editor, was pushed through to a successful conclusion and published on May 25, 1940. Several studies of Shoshonean archeology and ethnology were written and published.

May 26 to July 1 was spent by Dr. Steward among the Carrier Indians of British Columbia. Records of land tenure, subsistence activities, and sociopolitical changes during five generations were procured from the Stuart Lake and neighboring Carrier. It was found that within the framework of aboriginal land utilization, the sociopolitical structure had shifted from a band organization to a matrilineal clan and potlatch system derived from the coast. In historic times, the latter had given way before a patrilineal family system. Records of general ethnography, 100 specimens of native artifacts, and over 50 specimens of plants used in aboriginal times were also obtained.

In July 1939 a Latin-American bibliographic conference at Ann Arbor, Mich., was attended. In December 1939 two papers were read before the American Anthropological Association in Chicago. In May 1940 Dr. Steward served as secretary of the Anthropological Section of the Eighth American Scientific Congress, meeting in Washington.

Henry B. Collins, Jr., ethnologist, continued working over the material which he excavated in 1936 at prehistoric Eskimo village sites around Bering Strait. The collection from one of the sites—Kurigitavik, at Cape Prince of Wales—consists of several thousand artifacts of ivory, bone, stone, clay, wood, and baleen and provides a detailed

picture of prehistoric Eskimo culture of the intermediate Thule-Punuk stage, the age of which may be estimated at around a thousand years. The material from Kurigitavik, together with that from two earlier sites, has provided needed information on the transition from the Birnirk stage to the Thule, and collections from several later sites reveal the changes leading up to the culture of modern times.

Manuscripts completed during the year included a general paper summarizing the archeological evidence bearing on the origin of the Eskimo and the cultural position of this group in relation to neighboring peoples in Asia and America; and shorter papers on Eskimo art, on the voyages of Vitus Bering (for the Smithsonian radio series), and on prehistoric Indian crania from the Southeast.

Early in July 1939 Dr. William N. Fenton, associate anthropologist, left for Salamanca, N. Y., to conduct ethnobotanical studies among the Iroquois Indians of New York and Canada. He visited the Senecas of Allegany and Cornplanter Reservations, in southwestern New York and Pennsylvania, and the Mohawks of St. Regis Reservation, N. Y., and Caughnawaga, Province of Quebec. He called briefly on the Hurons of Lorette and the Mohawks of Oka, Lake of the Two Mountains, near Montreal. At Ottawa he studied the extensive catalog of Iroquois ethnological photographs in the National Museum of Canada. The month of August was passed among the Iroquois of Six Nations Reserve in Ontario, where he worked with Simeon Gibson, interpreter to the late J. N. B. Hewitt. About a hundred herbarium specimens were collected; when identified at the National Hebarium, these proved to be largely duplicates of medical plants gathered in previous years of field work among the Senecas. Moreover, interesting similarities of plant use and terminology were noted among Seneca, Mohawk, and Cayuga-Onondaga remnants who now live on widely separated reservations. Such resemblances suggest older basic Iroquois botanical concepts and medical practices. Photographs illustrating various activities in Iroquois herbalism comprise part of 100 negatives that were taken in the field. The early notes of F. W. Waugh were reviewed with Mohawk and Cayuga informants, and some paradigms in the several Iroquois dialects were recorded for comparative purposes. Returning to Allegany for the Green Corn Festival, Dr. Fenton reached Washington in mid-September.

During the winter's office work, Dr. Fenton read in the historical literature and located towns of the several Iroquois bands at successive periods in their history, with a view to outlining the major cultural problems arising from Iroquois tribal movements and conquests. This study, now published, attempts to begin for the Northeast the type of systematic approach that Dr. Swanton has accomplished for the Southeast. Dr. Fenton also published A Further Quest for Iroquois

Medicines, in Explorations and Field-Work of the Smithsonian Institution in 1939, and An Herbarium from the Allegany Senecas, in The Historic Annals of Southwestern New York. Several lectures on various aspects of Iroquois culture were delivered to Washington audiences, and in June, Dr. Fenton addressed a regional meeting of botanists at the Allegany School of Natural History on Iroquois Ethnobotany.

On May 2, 1940, Dr. Fenton again left for Salamanca to resume field work among the Seneca. Working primarily at Allegany Reservation, he also visited Tonawanda, collecting early spring medicinal plants. This season, work with informants was combined with a project to study Iroquois masks and ceremonial equipment in museums located near the Iroquois. At the close of the fiscal year, the extensive Converse collections in the New York State Museum (Albany) and Montgomery County Historical Society (Fort Johnson), and the Boyle and Chiefswood collections in the Royal Ontario Museum of Archaeology (Toronto) were measured and photographed. The pictures have proved to be useful in eliciting new material from informants and promise future usefulness in establishing local types of carving. A complete record of the mask-making technique has been made together with photographs of crucial stages in the process, and the rituals of several shamanistic societies have been taken with a flash camera for the first time. Dr. Fenton was engaged in field work at the close of the fiscal year.

SPECIAL RESEARCHES

Miss Frances Densmore, a collaborator of the Bureau, continued her study of Indian music chiefly by completing manuscripts for publication. A trip was made to Wisconsin Dells, Wis., to confer with Evergreen Tree, a Cochiti Indian, and to obtain further information concerning songs he recorded several years previously. Additional information concerning the peyote cult was also received from Winnebago informants in Wisconsin and Minnesota.

Nine manuscripts on pueblo music were recast and combined in a manuscript entitled "Music of Acoma, Isleta, and Cochiti Pueblos, New Mexico." Four manuscripts on "Choctaw Music," previously submitted, were similarly combined. The manuscript on "Winnebago Music" was completed, and a portion of the section on the peyote cult was restudied, extended, and retyped. These three manuscripts are now ready for publication.

Eleven manuscripts on the music of the Seminole in Florida were combined in a tentative manuscript of more than 300 pages. The number of transcribed Seminole songs now in possession of the

Bureau is 173 and these were arranged in a tentative order, corresponding to the order in the manuscript. About 70 Seminole songs, recorded in 1932 and 1933, have not yet been submitted to the Bureau. Work was begun on this material and a few of the songs were transcribed.

A peculiar custom observed in a few of the oldest Choctaw and Seminole songs consists in an embellishment of the melody in repetitions. It was found that the several renditions differed from one another and that the Indians were able to sing the simple melody, without the embellishments. These consisted in the addition of short, unimportant tones, without changing the trend of the melody. The custom resembles the improvisation which was noted in the songs of the Tule Indians of Panama and is in contrast to the exact repetitions of songs by northern tribes of Indians. A similar custom exists among Negroes on the Island of Trinidad in the British West Indies, and has been called Calypso.

According to Louis C. Elson (Curiosities of Music, p. 278, Oliver Ditson & Co., Boston, 1880), "The power of improvisation which is so well developed in the African Negro, is fully sustained by his descendants * * *."

Miss Densmore presented to the Bureau the original manuscript of an Onondaga Thanksgiving Song, written down for her in 1903 at Syracuse, N. Y., by Albert Cusick, a prominent Onondaga from the reservation near that city. The native words with their translation were also obtained. The song is in two parts, the lower being rhythmic and resembling a vocal accompaniment to the melody.

EDITORIAL WORK AND PUBLICATIONS

The editorial work of the Bureau has continued during the year under the immediate direction of the editor, M. Helen Palmer. There were issued three bulletins, as follows:

Bulletin 101. War ceremony and peace ceremony of the Osage Indians, by Francis La Flesche. vii+280 pp., 13 pls., 1 fig.

Bulletin 124. Nootka and Quileute music, by Frances Densmore. xxvi+358 pp., 24 pls., 7 figs.

Bulletin 125. Ethnography of the Fox Indians, by William Jones. Edited by Margaret Welpley Fisher. ix+156 pp.

The following bulletins were in press at the close of the fiscal year:

Bulletin 126. Archeological remains in the Whitewater District, Eastern Arizona. Part II. Artifacts and burials, by Frank H. H. Roberts, Jr. With appendix, Skeletal remains from the Whitewater District, Eastern Arizona, by T. D. Stewart.

Bulletin 127. Linguistic material from the tribes of southern Texas and northeastern Mexico, by John R. Swanton.

Bulletin 128. Anthropological papers, numbers 13–18.

No. 13. The mining of gems and ornamental stones by American Indians, by Sydney H. Ball.

No. 14. Iroquois suicide: A study in the stability of a culture pattern. by William N. Fenton.

No. 15. Tonawanda Longhouse ceremonies: Ninety years after Lewis Henry Morgan, by William N. Fenton.

No. 16. The Quichua-speaking Indians of the Province of Imbabura (Ecuador) and their anthropometric relations with the living populations of the Andean area, by John Gillin.

No. 17. Art processes in birchbark of the River Desert Algonquin, a circumboreal trait, by Frank G. Speck.

No. 18. Archeological reconnaissance of southern Utah, by Julian H. Steward.

Bulletin 129. An archeological survey of Pickwick Basin in the adjacent portions of the States of Alabama, Mississippi, and Tennessee, by William S. Webb and David L. De Jarnette. With additions by Walter P. Jones, J. P. E. Morrison, Marshall T. Newman and Charles E. Snow, and William G. Haag.

Bulletin 130. Archeological investigations at Buena Vista Lake, Kern County, California, by Waldo R. Wedel. With appendix, Skeletal remains from Buena Vista sites, California, by T. Dale Stewart.

Bulletin 131. Peachtree Mound and village site, Cherokee County, North Carolina, by Frank M. Setzler and Jesse D. Jennings. With appendix, Skeletal remains from the Peachtree Site, North Carolina, by T. Dale Stewart.

Publications distributed totaled 13,984.

LIBRARY

There has been no change in the library staff during the fiscal year. Accessions during the fiscal year totaled 364.

The section of North American periodicals has been reclassified and reshelved and a temporary shelf list made. Permanent catalog and shelf-list cards have been made for part of this material.

The library staff has relabeled and reshelved 4,687 books. All these are now in the Library of Congress classification. As of June 30, 1940, practically all North American material has been reclassified and reshelved, almost all Central and South American material, and about two-thirds of the sections on ethnology other than American. Library of Congress cards have been ordered when available for all books reclassified which did not already have them. Practically all these cards have been prepared and filed in the catalog.

The Librarian attended the meetings of the Inter-American Bibliographical and Library Association at Washington, D. C., in February and the meetings of the Eighth American Scientific Congress at Washington in May.

ILLUSTRATIONS

Following is a summary of work accomplished during the fiscal year by E. G. Cassedy, illustrator:

Line drawings	152	Photographs retouched	35
Stipple drawings	4	Negatives retouched	25
Wash drawings	14	Charts	3
Lettering jobs	184	Mechanical drawings	5
Plates assembled	54		
Graphs	22	Total	515
Maps	17		

MISCELLANEOUS

During the course of the year information was furnished by members of the Bureau staff in reply to numerous inquiries concerning the North American Indians, both past and present, and the Mexican peoples of the prehistoric and early historic periods. Various specimens sent to the Bureau were identified and data on them furnished for their owners.

Personnel.—Miss M. H. Palmer was appointed on July 1, 1939, as editor to fill the vacancy caused by the retirement of Stanley Searles. Miss Ethelwyn E. Carter, junior stenographer, resigned on September 17, 1939, and Mrs. Catherine M. Phillips was appointed on November 6, 1939, to fill this vacancy.

Respectfully submitted.

M. W. Stirling, *Chief.*

Dr. C. G. Abbot,
Secretary, Smithsonian Institution.

APPENDIX 6

REPORT ON THE INTERNATIONAL EXCHANGE SERVICE

SIR: I have the honor to submit the following report on the activities of the International Exchange Service during the fiscal year ended June 30, 1940:

The congressional appropriation was $44,880, an increase of $280 over 1939, the extra amount having been allowed for step-ups in the salaries of certain exchange employees. The collections from repayments amounted to $4,112.24, making the total available resources $48,992.24.

During the year 639,344 packages passed through the service, a decrease of 75,533. The weight was 527,545 pounds, a decrease of 192,149 pounds. These large decreases in the number and weight of packages were due to the interruption of shipments of exchanges between the United States and a number of foreign countries caused by the wars in Europe and in China.

The number and weight of packages sent and received through the service is given in the following table:

	Packages		Weight	
	Sent	Received	Sent	Received
			Pounds	*Pounds*
United States parliamentary documents sent abroad	342,246		137,948	
Publications received in return for parliamentary documents		5,477		14,247
United States departmental documents sent abroad	120,681		119,332	
Publications received in return for departmental documents		6,254		17,790
Miscellaneous scientific and literary publications sent abroad	132,052		178,995	
Miscellaneous scientific and literary publications received from abroad for distribution in the United States		32,634		59,233
Total	594,979	44,365	436,275	91,270
Grand total	639,344		527,545	

There were shipped abroad 1,894 boxes, a decrease of 1,129 boxes from the preceding year. Of these boxes, 486 were for depositories of full sets of United States governmental documents, and the remainder were for miscellaneous institutions and individuals. The very large decrease in the number of boxes shipped abroad was due, as stated above, to the interruption of the normal activities of the Exchange Service by the foreign wars.

In addition to the packages transmitted abroad in boxes, there were forwarded by mail, postage paid, 95,317 packages, an increase of 4,962 over last year. Also, a large number of packages are sent directly to their destinations by mail under Government frank, an arrangement for the franking privilege having been made between the postal authorities of the United States and those of certain foreign countries. A list of the countries with which this privilege is in effect is as follows: Canada, Chile, Colombia, Costa Rica, Cuba, Dominican Republic, Ecuador, Guatemala, Haiti, Honduras, Mexico, Newfoundland (including Labrador), Nicaragua, Panama, Paraguay, Peru, Salvador, Uruguay, and Venezuela.

The European war, which began September 3, 1939, has greatly interrupted the activities of the International Exchange Service. At the close of the fiscal year the interchange of publications was suspended between the United States and all European countries except Great Britain, Finland, and the Soviet Republic. Shipments to Finland are being made via Petsamo, and shipments to the U. S. S. R., by way of Vladivostok.

On account of the Japanese invasion of China, the Chinese Bureau of International Exchanges was moved from Nanking to Chungking and the Institution forwarded several large consignments to that bureau via Haiphong, French Indochina. That channel of transmission, however, was closed during the middle of the year owing to operations of the Japanese in that section. Shipments of exchanges for the Library Association of China and the other organizations mentioned in the preceding report that have set up temporary quarters in Hong Kong are being continued.

At the outbreak of the European war the London School of Economics and Political Science wrote the Institution that

> it is intended to maintain the work of this Library as usual despite the outbreak of hostilities between Great Britain and Germany and that accordingly it would be much appreciated if shipments of United States official documents would be sent to the Library as usual.

On account of difficulties in shipping conditions caused by the war it was not possible immediately to transmit consignments to Great Britain. When, in January 1940, transmissions to that country were resumed, the Librarian of the London School wrote the Institution in part as follows:

> In this matter I have been in close touch with the Librarian of the Patent Office, which regularly receives U. S. patent specifications through your agency. I know he would wish to join with me in saying that we are very sensible of our obligations to you in this matter, and, whilst deploring the additional work and inconvenience which are inevitably caused to you at the present time, warmly appreciate the invaluable assistance you are rendering to learned work in this country.

In June the French Bureau of International Exchanges informed the Institution that 5 boxes forwarded to that bureau in April were destroyed by fire at the Havre Railroad Station on the night of May 19. Another consignment, consisting of 5 boxes, forwarded in December 1939 to the Royal Danish Academy of Sciences in Copenhagen, according to a report made by the American Scantic Line, was destroyed on the dock in Bergen, Norway, by fire caused by airplane bombardment on April 14, 1940.

The above-mentioned consignments are the only shipments that have been lost during the war, so far as have been reported to the Institution. No doubt a few others have been lost in transit, but definite information regarding the matter will not be received until the end of the war.

In April 1940 a letter was received from Dr. A. Holmberg, Chief Librarian, Royal Swedish Academy of Sciences, Stockholm, stating that the work performed by that Academy in distributing exchange packages to Swedish correspondents henceforth would be assumed by the Royal Library.

The Smithsonian system of international exchanges between the United States and foreign countries has been in operation for 90 years, during 72 of which the Academy of Sciences has acted as the Swedish exchange distributing agency. Two other establishments, which at the same time (1868) took over the distribution of packages for correspondents in their countries, are still carrying on the exchange work—the Royal Norwegian University and the Royal Danish Academy of Sciences.

Shipments of exchanges to Spain, which have been held up since 1936, were resumed in April 1940; but, on account of the disruption to shipping conditions due to the spread of the European war, it was not possible to continue transmissions to that country.

FOREIGN DEPOSITORIES OF GOVERNMENTAL DOCUMENTS

Sets of United States governmental documents are now forwarded to 104 foreign depositories, a decrease of 4 sets from last year. Sixty of these depositories receive full sets and 44, partial sets. The sets that were discontinued were for the Province of Buenos Aires, Danzig, Lübeck, and Vienna.

The depository in Brazil was changed from the Bibliotheca Nacional to Instituto Nacional do Livro, Rio de Janeiro. The depository in Mexico was changed from Departamento Autónomo de Prensa y Publicidad to Dirección General de Información, Mexico, D. F. The Nicaraguan depository was changed from the Superintendente de Archivos Nacionales, Managua, to Ministerio de Relaciones Exteriores, Managua.

DEPOSITORIES OF FULL SETS

ARGENTINA: Dirección de Investigaciones, Archivo y Propaganda, Ministerio de Relaciones Exteriores y Culto, Buenos Aires.
AUSTRALIA: Commonwealth Parliament and National Library, Canberra.
  NEW SOUTH WALES: Public Library of New South Wales, Sydney.
  QUEENSLAND: Parliamentary Library, Brisbane.
  SOUTH AUSTRALIA: Parliamentary Library, Adelaide.
  TASMANIA: Parliamentary Library, Hobart.
  VICTORIA: Public Library of Victoria, Melbourne.
  WESTERN AUSTRALIA: Public Library of Western Australia, Perth.
BELGIUM: Bibliothèque Royale, Bruxelles.
BRAZIL: Instituto Nacional do Livro, Rio de Janeiro.
CANADA: Library of Parliament, Ottawa.
  MANITOBA: Provincial Library, Winnipeg.
  ONTARIO: Legislative Library, Toronto.
  QUEBEC: Library of the Legislature of the Province of Quebec.
CHILE: Biblioteca Nacional, Santiago.
CHINA: Bureau of International Exchange, Ministry of Education, Chungking.
COLOMBIA: Biblioteca Nacional, Bogotá.
COSTA RICA: Oficina de Depósito y Canje Internacional de Publicaciones, San José.
CUBA: Secretaría de Estado, Dirección de Relaciones Culturales, Habana.
CZECHOSLOVAKIA: Bibliothèque de l'Assemblée Nationale, Prague.
DENMARK: Kongelige Danske Videnskabernes Selskab, Copenhagen.
EGYPT: Bureau des Publications, Ministère des Finances, Cairo.
ESTONIA: Riigiraamatukogu (State Library), Tallinn.
FINLAND: Parliamentary Library, Helsingfors.
FRANCE: Bibliothèque Nationale, Paris.
GERMANY: Reichstauschstelle im Reichsministerium für Wissenschaft, Erziehung und Volksbildung, Berlin, N. W. 7.
  AUSTRIA: National-Bibliothek, Wien, I.
  BADEN: Universitäts-Bibliothek, Freiburg. (Depository of the State of Baden.)
  BAVARIA: Bayerische Staatsbibliothek, München.
  PRUSSIA: Preussische Staatsbibliothek, Berlin, N. W. 7.
  SAXONY: Sächsische Landesbibliothek, Dresden—N. 6.
  WURTEMBURG: Landesbibliothek, Stuttgart.
GREAT BRITAIN:
  ENGLAND: British Museum, London.
  LONDON: London School of Economics and Political Science. (Depository of the London County Council.)
HUNGARY: Library, Hungarian House of Delegates, Budapest.
INDIA: Imperial Library, Calcutta.
IRELAND: National Library of Ireland, Dublin.
ITALY: Ministero dell'Educazione Nazionale, Rome.
JAPAN: Imperial Library of Japan, Tokyo.
LATVIA: Bibliothèque d'État, Riga.
LEAGUE OF NATIONS: Library of the League of Nations, Geneva, Switzerland.
MEXICO: Dirección General de Información, Mexico, D. F.
NETHERLANDS: Royal Library, The Hague.
NEW ZEALAND: General Assembly Library, Wellington.

NORTHERN IRELAND: H. M. Stationery Office, Belfast.
NORWAY: Universitets-Bibliothek, Oslo. (Depository of the Government of Norway.)
PERU: Sección de Propaganda y Publicaciones, Ministerio de Relaciones Exteriores, Lima.
POLAND: Bibliothèque Nationale, Warsaw.
PORTUGAL: Bibliotheca Nacional, Lisbon.
RUMANIA: Academia Românǎ, Bucharest.
SPAIN: Cambio Internacional de Publicaciones, Avenida de Calvo Sotelo 20, Madrid.
SWEDEN: Kungliga Biblioteket, Stockholm.
SWITZERLAND: Bibliothèque Centrale Fédérale, Berne.
TURKEY: Department of Printing and Engraving, Ministry of Education, Istanbul.
UNION OF SOUTH AFRICA: State Library, Pretoria, Transvaal.
UNION OF SOVIET SOCIALIST REPUBLICS: All-Union Lenin Library, Moscow 115.
UKRAINE: All-Ukrainian Association for Cultural Relations with Foreign Countries, Kiev.
URUGUAY: Oficina de Canje Internacional de Publicaciones, Montevideo.
VENEZUELA: Biblioteca Nacional, Caracas.
YUGOSLAVIA: Ministère de l'Education, Belgrade.

DEPOSITORIES OF PARTIAL SETS

AFGHANISTAN: Ministry of Foreign Affairs, Publications Department, Kabul.
BOLIVIA: Biblioteca del H. Congreso Nacional, La Paz.
BRAZIL:
MINAS GERAES: Directoria Geral de Estatistica em Minas, Bello Horizonte.
RIO DE JANEIRO: Bibliotheca da Assemblea Legislativa do Estado, Nictheroy.
BRITISH GUIANA: Government Secretary's Office, Georgetown, Demerara.
BULGARIA: Ministère des Affaires Étrangères, Sofia.
CANADA:
ALBERTA: Provincial Library, Edmonton.
BRITISH COLUMBIA: Provincial Library, Victoria.
NEW BRUNSWICK: Legislative Library, Fredericton.
NOVA SCOTIA: Provincial Secretary of Nova Scotia, Halifax.
PRINCE EDWARD ISLAND: Legislative Library, Charlottetown.
SASKATCHEWAN: Legislative Library, Regina.
CEYLON: Chief Secretary's Office (Record Department of the Library), Colombo.
CHINA: National Library of Peiping, % Fung Ping Shan Chinese Library, Hong Kong.
DOMINICAN REPUBLIC: Biblioteca del Senado, Ciudad Trujillo.
ECUADOR: Biblioteca Nacional, Quito.
GERMANY:
BREMEN: Staatsbibliothek.
HAMBURG: Staats-und Universitäts-Bibliothek.
HESSE: Universitäts-Bibliothek, Giessen.
THURINGIA: Rothenberg-Bibliothek, Landesuniversität, Jena.
GREECE: Library of Parliament, Athens.
GUATEMALA: Biblioteca Nacional, Guatemala.
HAITI: Secrétaire d'État des Relations Extérieures, Port-au-Prince.
HONDURAS: Biblioteca y Archivo Nacionales, Tegucigalpa.
ICELAND: National Library, Reykjavik.

INDIA:

BENGAL: Secretary, Bengal Legislative Council Department, Council House, Calcutta.

BIHAR AND ORISSA: Revenue Department, Patna.

BOMBAY: Undersecretary to the Government of Bombay, General Department, Bombay.

BURMA: Secretary to the Government of Burma, Education Department, Rangoon.

MADRAS: Chief Secretary to the Government of Madras, Public Department, Madras.

PUNJAB: Chief Secretary to the Government of the Punjab, Lahore.

UNITED PROVINCES OF AGRA AND OUDH: University of Allahabad, Allahabad.

JAMAICA: Colonial Secretary, Kingston.

LIBERIA: Department of State, Monrovia.

LITHUANIA: Ministère des Affaires Étrangères, Kaunas (Kovno).

MALTA: Minister for the Treasury, Valletta.

NEWFOUNDLAND: Department of Home Affairs, St. John's.

NICARAGUA: Ministerio de Relaciones Exteriores, Managua.

PANAMA: Secretaría de Relaciones Exteriores, Panama.

PARAGUAY: Secretario de la Presidencia de la República, Asunción.

SALVADOR: Ministerio de Relaciones Exteriores, San Salvador.

STRAITS SETTLEMENTS: Colonial Secretary, Singapore.

THAILAND: Department of Foreign Affairs, Bangkok.

VATICAN CITY: Biblioteca Apostolica Vaticana, Vatican City, Italy.

INTERPARLIAMENTARY EXCHANGE OF THE OFFICIAL JOURNAL

There are sent to foreign depositories 104 copies of the Congressional Record and the Federal Register. A list of the depositories of those documents is given below:

DEPOSITORIES OF CONGRESSIONAL RECORD

ALBANIA: Ministrija Mbretnore e Punëvetë Jashtme, Tirana.

ARGENTINA:

Biblioteca del Congreso Nacional, Buenos Aires.

Cámara de Diputados, Oficina de Información Parlamentaria, Buenos Aires.

Boletín Oficial de la República Argentina, Ministerio de Justicia e Instrucción Pública, Buenos Aires.

AUSTRALIA:

Library of the Commonwealth Parliament, Canberra.

NEW SOUTH WALES: Library of Parliament of New South Wales, Sydney.

QUEENSLAND: Chief Secretary's Office, Brisbane.

WESTERN AUSTRALIA: Library of Parliament of Western Australia, Perth.

BELGIUM: Bibliothèque de la Chambre des Représentants, Bruxelles.

BRAZIL:

Bibliotheca do Congresso Nacional, Rio de Janeiro.

AMAZONAS: Archivo, Bibliotheca e Imprensa Publica, Manáos.

BAHIA: Governador do Estado da Bahia, São Salvador.

ESPIRITO SANTO: Presidencia do Estado do Espirito Santo, Victoria.

RIO GRANDE DO SUL: "A Federação," Porto Alegre.

SERGIPE: Bibliotheca Publica do Estado de Sergipe, Aracajú.

SÃO PAULO: Diario Official do Estado de São Paulo, São Paulo.

BRITISH HONDURAS: Colonial Secretary, Belize.

CANADA:

Library of Parliament, Ottawa.

Clerk of the Senate, Houses of Parliament, Ottawa.

CHINA: National Central Library, Nanking.

CUBA: Biblioteca del Capitolio, Habana.

CZECHOSLOVAKIA: Bibliothèque de l'Assemblée Nationale, Prague.

DENMARK: Rigsdagens Bureau, Copenhagen.

EGYPT:

Chambres des Députés, Cairo.

Sénat, Cairo.

FRANCE:

Chambre des Députés, Service de l'Information Parlementaire Étrangère, Paris.

Bibliothèque du Sénat, au Palais du Luxembourg, Paris.

Bureau de Documentation Générale, Ministère des Finances, Paris I.

Bibliothéque, Direction des Accords commerciaux, Ministére du Commerce, Paris.

GERMANY:

Deutsche Reichstags-Bibliothek, Berlin, N. W. 7.

Reichsfinanzministerium, Berlin, W. 8.

ANHALT: Anhaltische Landesbücherei, Dessau.

AUSTRIA: Bibliothek im Parlament, Wien I.

BRAUNSCHWEIG: Bibliothek des Braunschweigischen Staatministeriums, Braunschweig.

MECKLENBURG: Staatsministerium, Schwerin.

OLDENBURG: Oldenburgisches Staatsministerium, Oldenburg i. O.

SCHAUMBURG-LIPPE: Schaumburg-Lippische Landesregierung, Bücheburg.

GIBRALTAR: Gibraltar Garrison Library Committee, Gibraltar.

GREAT BRITAIN: Library of the Foreign Office, London.

GREECE: Library of Parliament, Athens.

GUATEMALA: Biblioteca de la Asamblea Legislativa, Guatemala.

HONDURAS: Biblioteca del Congreso Nacional, Tegucigalpa.

HUNGARY: A Magyar országgyülés könyvtará, Budapest.

INDIA: Legislative Department, Simla.

INDOCHINA: Gouverneur Général de l'Indochine, Hanoi.

IRAN: Library of the Iranian Parliament, Téhéran.

IRAQ: Chamber of Deputies, Baghdad.

IRISH FREE STATE: Dail Eireann, Dublin.

ITALY:

Biblioteca della Camera dei Fasci e delle Corporazione, Rome.

Biblioteca del Senato del Regno, Rome.

Ufficio degli Studi Legislativi, Senato del Regno, Rome.

LATVIA: Valsts Biblioteka, Riga.

LEAGUE OF NATIONS: Library of the League of Nations, Geneva, Switzerland.

LEBANON: Ministère des Finances de la République Libanaise, Service du Matériel, Beirut.

LIBERIA: Department of State, Monrovia.

MEXICO: Dirección General de Información, Mexico, D. F.

AGUASCALIENTES: Gobernador del Estado de Aguascalientes, Aguascalientes.

CAMPECHE: Gobernador del Estado de Campeche, Campeche.

CHIAPAS: Gobernador del Estado de Chiapas, Tuxtla Gutierrez.

CHIHUAHUA: Gobernador del Estado de Chihuahua, Chihuahua.

MEXICO—Continued.

COAHUILA: Periódico Oficial del Estado de Coahuila, Palacio de Gobierno, Saltillo.

COLIMA: Gobernador del Estado de Colima, Colima.

DURANGO: Gobernador Constitucional del Estado de Durango, Durango.

GUANAJUATO: Secretaría General de Gobierno del Estado, Guanajuato.

GUERRERO: Gobernador del Estado de Guerrero, Chilpancingo.

JALISCO: Biblioteca del Estado, Guadalajara.

LOWER CALIFORNIA: Gobernador del Distrito Norte, Mexicali.

MEXICO: Gaceta del Gobierno, Toluca.

MICHOACÁN: Secretaría General de Gobierno del Estado de Michoacán, Morelia.

MORELOS: Palacio de Gobierno, Cuernavaca.

NAYARIT: Gobernador de Nayarit, Tepic.

NUEVO LEON: Biblioteca del Estado, Monterey.

OAXACA: Periódico Oficial, Palacio de Gobierno, Oaxaca.

PUEBLA: Secretaría General de Gobierno, Puebla.

QUERETARO: Secretaría General de Gobierno, Sección de Archivo, Queretaro.

SAN LUIS POTOSI: Congreso del Estado, San Luis Potosi.

SINALOA: Gobernador del Estado de Sinaloa, Culiacan.

SONORA: Gobernador del Estado de Sonora, Hermosillo.

TABASCO: Secretaría General de Gobierno, Sección 3a, Ramo de Prensa, Villahermosa.

TAMAULIPAS: Secretaría General de Gobierno, Victoria.

TLAXCALA: Secretaría de Gobierno del Estado, Tlaxcala.

VERA CRUZ: Gobernador del Estado de Vera Cruz, Departamento de Gobernación y Justicia, Jalapa.

YUCATÁN: Gobernador del Estado de Yucatán, Mérida, Yucatán.

NETHERLANDS: Bibliotheek van de Tweede Kamer der Staten-General, The Hague.

NETHERLANDS INDIES: Volksraad von Nederlandsch-Indië, Batavia, Java.

NEW ZEALAND: General Assembly Library, Wellington.

NORWAY: Storthingets Bibliothek, Oslo.

PERU: Cámara de Diputados, Lima.

POLAND: Bibljoteka Narodowa, Warsaw.

PORTUGAL: Secretario da Assemblea Nacional, Lisboa.

RUMANIA:

Bibliothèque de la Chambre des Députés, Bucharest.

Ministère des Affaires Étrangères, Bucharest.

SPAIN:

Biblioteca del Congreso Nacional, Madrid.

CATALUNYA: Biblioteca del Parlament de Catalunya, Barcelona.

SWITZERLAND: Bibliothèque de l'Assemblée Fédérale Suisse, Berne

BERN: Staatskanzlei des Kantons Bern.

ST. GALLEN: Staatskanzlei des Kantons St. Gallen.

SCHAFFHAUSEN: Staatskanzlei des Kantons Schaffhausen.

ZÜRICH: Staatskanzlei des Kantons Zürich.

TURKEY: Turkish Grand National Assembly, Ankara.

UNION OF SOUTH AFRICA:

Library of Parliament, Cape Town, Cape of Good Hope.

State Library, Pretoria, Transvaal.

URUGUAY: Diario Oficial, Calle Florida 1178, Montevideo.

VENEZUELA: Biblioteca del Congreso, Caracas.

VATICAN CITY: Biblioteca Apostolica Vaticana, Vatican City, Italy.

FOREIGN EXCHANGE AGENCIES

A list of the foreign agencies through which the exchange of publications is effected is given below. Most of those agencies forward consignments to the Institution for distribution in the United States.

LIST OF AGENCIES

ALGERIA, via France.

ANGOLA, via Portugal.

ARGENTINA: Comisión Protectora de Bibliotecas Populares, Canje Internacional, Calle Callao 1540, Buenos Aires.

AUSTRIA, via Germany.

AZORES, via Portugal.

BELGIUM: Service Belge des Échanges Internationaux, Bibliothèque Royale de Belgique, Bruxelles.

BOLIVIA: Sent by mail.

BRAZIL: Serviço de Permutações Internacionaes, Bibliotheca Nacional, Rio de Janeiro.

BRITISH GUIANA: Sent by mail.

BRITISH HONDURAS: Sent by mail.

BULGARIA: Sent by mail.

CANADA: Sent by mail.

CANARY ISLANDS, via Spain.

CHILE: Sent by mail.

CHINA: Bureau of International Exchange, Ministry of Education, Chungking.

COLOMBIA: Sent by mail.

COSTA RICA: Sent by mail.

CUBA: Sent by mail.

CZECHOSLOVAKIA: Service des Echanges Internationaux, Bibliothèque de l'Assemblée Nationale, Prague 1–79.

DANZIG: Sent by mail.

DENMARK: Service Danois des Échanges Internationaux, Kongelige Danske Videnskabernes Selskab, Copenhagen V.

DOMINICAN REPUBLIC: Sent by mail.

ECUADOR: Sent by mail.

EGYPT: Government Press, Publications Office, Bulaq, Cairo.

ESTONIA: Riigiraamatukogu (State Library), Tallinn.

FINLAND: Delegation of the Scientific Societies of Finland, Kasärngatan 24, Helsingfors.

FRANCE: Service Français des Échanges Internationaux, 110 Rue de Grenelle, Paris.

FRENCH GUIANA: Sent by mail.

GERMANY: Amerika-Institut, Universitätstrasse 8, Berlin, N. W. 7.

GREAT BRITAIN AND IRELAND: Wheldon & Wesley, 721 North Circular Road, Willesden, London, NW. 2.

GREECE: Sent by mail.

GREENLAND, via Denmark.

GUATEMALA: Sent by mail.

HAITI: Sent by mail.

HONDURAS: Sent by mail.

HUNGARY: Hungarian Libraries Board, Ferenciektere 5, Budapest, IV.

ICELAND, via Denmark.

INDIA: Superintendent of Government Printing and Stationery, Bombay.

ITALY: Ufficio degli Scambi Internazionali, Ministero dell'Educazione Nazionale, Rome.

JAMAICA: Sent by mail.

JAPAN: International Exchange Service, Imperial Library of Japan, Uyeno Park, Tokyo.

LATAKIA: Sent by mail.

LATVIA: Service des Échanges Internationaux, Bibliothèque d'Etat de Lettonie, Riga.

LEBANON: Sent by mail.

LIBERIA: Sent by mail.

LITHUANIA: Sent by mail.

LUXEMBOURG, via Belgium.

MADAGASCAR, via France.

MADEIRA, via Portugal.

MEXICO: Sent by mail.

MOZAMBIQUE, via Portugal.

NETHERLANDS: International Exchange Bureau of the Netherlands, Royal Library, The Hague.

NETHERLANDS INDIES: Sent by mail.

NEWFOUNDLAND AND LABRADOR: Sent by mail.

NEW SOUTH WALES: Public Library of New South Wales, Sydney.

NEW ZEALAND: General Assembly Library, Wellington.

NICARAGUA: Sent by mail.

NORWAY: Service Norvégien des Échanges Internationaux, Bibliothèque de l'Université Royale, Oslo.

PALESTINE: Jewish National and University Library, Jerusalem.

PANAMA: Sent by mail.

PARAGUAY: Sent by mail.

PERU: Sent by mail.

POLAND: Service Polonais des Échanges Internationaux, Bibliothèque Nationale, Warsaw.

PORTUGAL: Secção de Trocas Internacionaes, Bibliotheca Nacional, Lisboa.

QUEENSLAND: Bureau of Exchanges of International Publications, Chief Secretary's Office, Brisbane.

RUMANIA: Soussecrétariat d'Etat de la Propagande, Direction de la Presse, Service des Échanges Internationaux, Bucharest.

SALVADOR: Sent by mail.

SOUTH AUSTRALIA: South Australian Government Exchanges Bureau, Government Printing and Stationery Office, Adelaide.

SPAIN: Cambio Internacional de Publicaciónes, Avenida de Calvo Sotelo 20, Madrid.

SURINAM: Sent by mail.

SWEDEN: Kongliga Biblioteket, Stockholm.

SWITZERLAND: Service Suisse des Échanges Internationaux, Bibliothèque Centrale Fédérale, Berne.

SYRIA: Sent by mail.

TASMANIA: Secretary to the Premier, Hobart.

THAILAND: Sent by mail.

TRINIDAD: Sent by mail.

TUNIS, via France.

TURKEY: Ministry of Education, Department of Printing and Engraving, Istanbul.

UNION OF SOUTH AFRICA: Government Printing and Stationery Office, Capetown, Cape of Good Hope.

UNION OF SOVIET SOCIALIST REPUBLICS: Library of the Academy of Sciences of the U. S. S. R., Exchange Service, Leningrad, V. O.

URUGUAY: Sent by mail.

VENEZUELA: Sent by mail.

VICTORIA: Public Library of Victoria, Melbourne.

WESTERN AUSTRALIA: Public Library of Western Australia, Perth.

YUGOSLAVIA: Section des Échanges Internationaux, Ministère des Affaires Étrangères, Belgrade.

Mr. Frank E. Gass, who has been with the Institution for 54 years, having been appointed August 1, 1886, as a messenger boy and who is now correspondence clerk of the International Exchanges, reached the statutory retirement age in February but was granted an extension of 1 year.

Respectfully submitted.

C. W. SHOEMAKER, *Chief Clerk.*

Dr. C. G. ABBOT,
Secretary, Smithsonian Institution.

APPENDIX 7

REPORT ON THE NATIONAL ZOOLOGICAL PARK

SIR: I have the honor to submit the following report on the operations of the National Zoological Park for the fiscal year ended June 30, 1940:

The regular appropriation made by Congress was $237,060, all of which was expended.

FUNCTIONS OF THE ZOO

The National Zoological Park is far more than merely a recreation place; an eminent scientific man once referred to it as "a museum of living animals." Every day in the year thousands of people visit the Zoo. Some come merely for enjoyment and recreation, but others come with definite purposes in mind. Among them are many students both primary and advanced. Artists, photographers, and research workers all find material and inspiration for their studies and are afforded all possible facilities. Research of any kind that can be carried on without harm to the animals is encouraged.

Such organizations as the Audubon Society, Girl Scouts, Boy Scouts, geological classes, and others regularly come to the Zoo to study the native wildlife and interesting geological formations in the Park. Requests for technical information regarding animals and zoos are constantly received at the Zoo office by personal inquiry, telephone calls, and letters from all over the world.

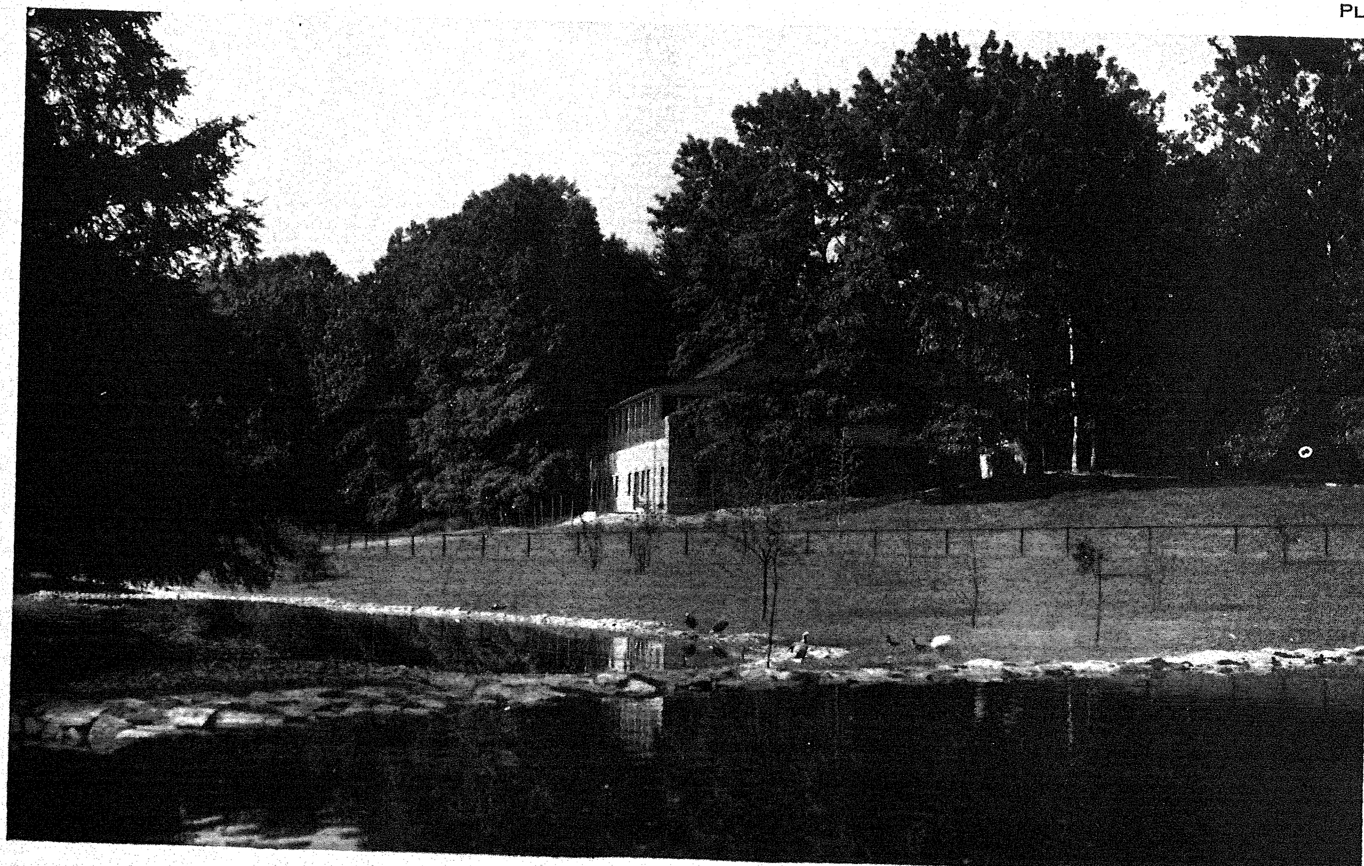
IMPROVEMENTS

Continuance of W. P. A. assistance resulted in the completion of the following work during the year:

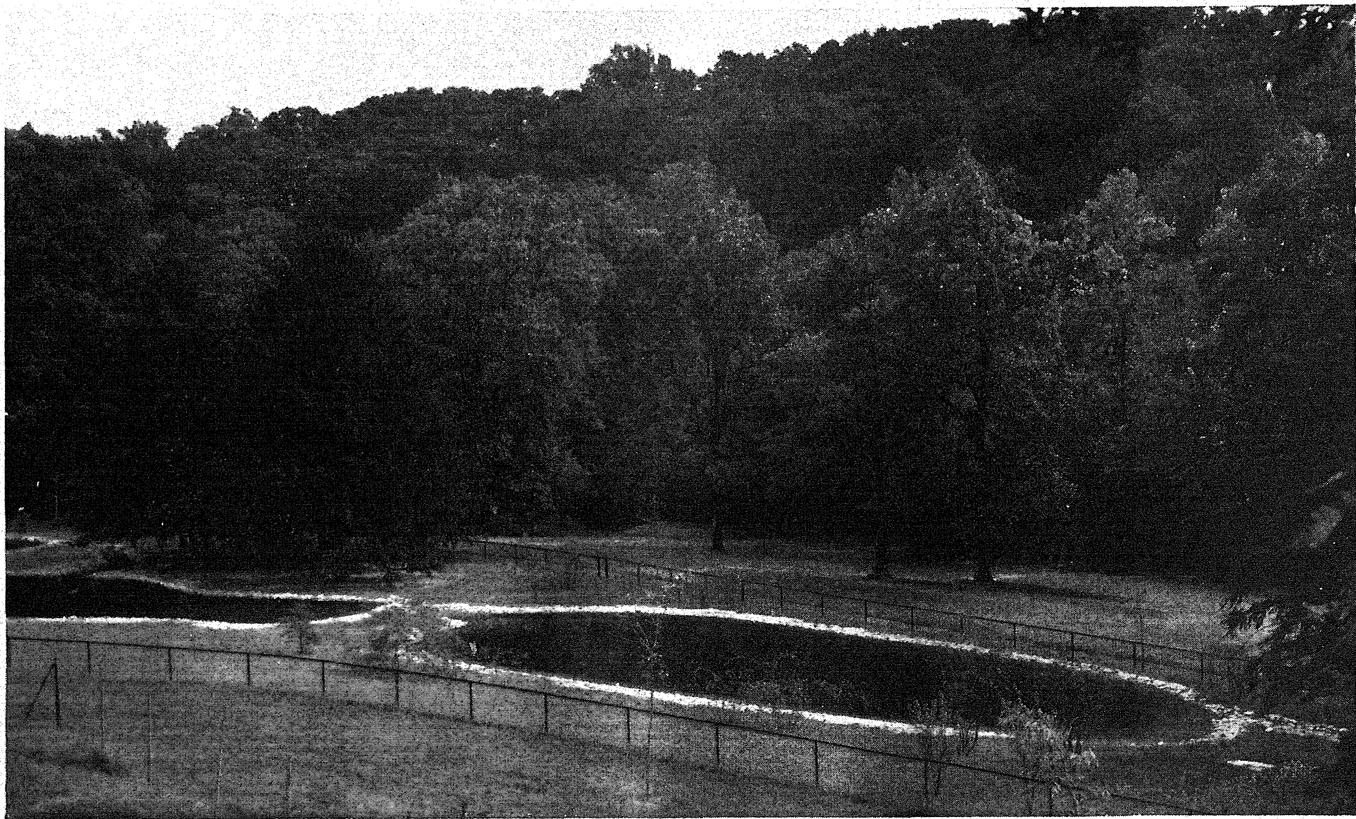
Four paddocks about 80 by 150 feet were constructed along the road above the American bison. These are the barless-pit type without obstruction to the view between the people and the animals.

Five paddocks were constructed across from the large-mammal house. These average about 50 by 60 feet and are designed to accommodate the American representatives of the camel family, llama, alpaca, vicuna, and guanaco. These paddocks are likewise of the barless-pit type and can accommodate a considerable variety of animals in addition to those listed above.

A series of four waterfowl ponds was constructed across the road from the old waterfowl pond. The pools are cement-lined, but from a



NEW RESTAURANT BUILDING AT THE NATIONAL ZOOLOGICAL PARK.



VIEW FROM NEW RESTAURANT BUILDING AT THE NATIONAL ZOOLOGICAL PARK, SHOWING NEW WATERFOWL PONDS.

few inches below the water level to above the water level they are faced with stone to represent an ideal section of the geology of this region. The placement of the stone was done under the supervision of Dr. Ray S. Bassler, Head Curator, Department of Geology, National Museum. The entire area, which is much larger than the old waterfowl yard, is enclosed by a low fence. This is one of the most attractive additions to the Park in many years; it will accommodate a far greater number and variety of waterfowl than it has ever been possible before to exhibit, and in addition it is so situated that it will be seen by practically all persons visiting the Zoo.

Cement curbing to the extent of 9,000 linear feet was constructed along the roadsides. This is a preliminary to what is hoped will eventually result in a general improvement of the roads within the Zoo grounds. New walks laid totaled 2,050 square feet. This includes a walk and steps up the lion-house hill. About 3,000 square yards of roads and walks were repaired.

An enclosure was constructed between the bears and the road on a site that was for many years unattractive although it was in a very conspicuous location. This will be suitable for medium-sized animals. It is also of the barless-moat type of construction on the front.

At the end of the fiscal year there is practically completed an enclosure on the south side of the reptile house that will accommodate such animals as lizards, snakes, crocodilians, and turtles. This is provided with a pool; a moat keeps the animals in their enclosure but offers no obstruction to the view of the public.

Extensive plantings were made on areas that had been or were being newly developed. These plantings consisted mainly of trees that either produce nuts or fruits suitable for the wildlife of the Park or are ornamental or shade trees. Also many flowering or other ornamental shrubs and evergreens were planted.

Work was begun in March 1940 on a new restaurant to be constructed by the P. W. A. under an allotment of $90,000. The restaurant building, of the Virginia tavern type of stone construction, is situated in a grove of trees across the road from the lion house, commanding a beautiful view of the new waterfowl ponds. The building will probably be completed by the end of September 1940.

NEEDS OF THE ZOO

The chief need of the Zoo at the present time is for proper buildings in which to exhibit:

1. *Antelopes, tropical deer, wild hogs, kangaroos.*—The present building is dilapidated and unsightly, a fire hazard, and a menace to the health of animals.

2. *Monkeys.*—The Zoo has an exceedingly fine collection of monkeys, both in number and in kind, which are very poorly exhibited in the antiquated building which at present houses them.

3. *Carnivores.*—Either the present building should be entirely reconstructed, utilizing the one wing that is well built and replacing the old frame wing—a firetrap and not suitable for the housing or exhibition of these animals—or, much better, an entirely new and modern building should be erected.

When the W. P. A. is again available, there are a number of projects that should be carried out, including the replacing of old and dilapidated paddocks and shelters with new and modern ones.

It has been planned also to build a monkey island and a large outdoor cage for tigers.

The increase in utilization of the Park together with the increased structures and increase in area to be cared for has far outgrown the capacity of the existing personnel to care for it. It is, therefore, important, if the grounds and buildings are to be kept in a presentable condition, that the personnel be increased by at least 10 men. The rigid enforcement of the prohibition against W. P. A. workers doing any work of a maintenance character leaves no alternative other than to increase the personnel or allow the Park to be unsightly.

VISITORS FOR THE YEAR

A record of the attendance shows a slight decrease compared with last year.

July	258, 600	February	103, 300
August	200, 200	March	173, 800
September	264, 300	April	179, 200
October	154, 300	May	258, 600
November	130, 700	June	216, 100
December	140, 500		
January	50, 000	Total	2, 129, 600

The attendance of organizations, mainly classes of students, of which there is definite record, was 33,602, from 628 different schools in 21 States and the District of Columbia as follows:

State	Number of persons	Number of parties	State	Number of persons	Number of parties
Alabama	50	1	New Jersey	2, 161	27
Connecticut	146	3	New York	1, 228	25
Delaware	222	4	North Carolina	1, 010	30
District of Columbia	6, 706	123	Ohio	685	18
Florida	40	1	Pennsylvania	6, 293	116
Georgia	431	13	Rhode Island	70	1
Indiana	37	1	South Carolina	549	16
Maine	172	5	Tennessee	130	3
Maryland	5, 580	86	Virginia	5, 855	117
Massachusetts	672	17	West Virginia	1, 327	16
Michigan	152	4			
New Hampshire	86	1	Total	33, 602	628

About 3 o'clock every afternoon, except Sundays and holidays, a census is made of the cars parked on the Zoo grounds. During the year, 27,840 were so listed, representing every State in the Union, Alaska, Canada, Canal Zone, Cuba, Hawaii, Puerto Rico, and the Philippine Islands.

Since the total number is merely a record of those actually parked at one time, it is not of value as indicating a total attendance but is of importance as showing the percentage of attendance by States, Territories, and countries. The record for the year on this basis shows that the District of Columbia automobiles comprised slightly less than 46 percent; Maryland, 20 percent; Virginia, 10 percent; and the remaining cars were from other States, Territories, and countries. On a few occasions when it has been possible to make a census of the cars that were parked in the Zoo grounds at a given hour on Saturday afternoons, Sundays, and holidays, it has been found that District cars comprise only about 30 percent and cars from the several States and other parts of the world make the remaining 70 percent. Owing to the large attendance on these days, the proportion for the year of District and foreign cars would be very materially altered from that obtained when Saturdays, Sundays, and holidays are omitted from the count. It is, therefore, clearly evident that at least 60 percent of the cars that come to the Zoo throughout the year are from outside the District.

An accurate count of the total traffic through the Park would be desirable, and with that in mind a request has been made to the D. C. Works Progress Administration for such a project.

ACCESSIONS

FIELD WORK

SMITHSONIAN-FIRESTONE EXPEDITION

Through funds donated to the Smithsonian Institution by the Firestone Tire & Rubber Co., of Akron, Ohio, a party was sent to Liberia, West Africa, for the purpose of collecting specimens for the National Zoological Park. The party, consisting of the Director, Mrs. Mann, Ralph Norris, and Roy J. Jennier, sailed on the American-West African Line on February 17, 1940, for Monrovia. Here they were received by Mr. George Seybold, manager of the Firestone Plantations Co., and taken immediately to the plantation, where they established headquarters.

Trips into the interior were made at four localities: Belleyella, near the French Ivory Coast frontier; the Gibi country; the Polish Plantation at Reputa; and Bendaja in the Gola country, inland from Cape Mount and near the British Sierra Leone border. The party also visited the American Episcopal Missions at Bromley and Cape Mount

and were given cordial hospitality by Bishop Leopold Kroll and Miss Mary Wood McKenzie.

Much aid and hospitality were given by Mr. Seybold. He also spent some time at Cape Palmas and brought back a number of interesting specimens which he gave to the expedition. B. O. Vipond, Director of Personnel, was of great assistance as were various other plantation employees. P. C. Bodewes, with the aid of his native boys, made several drives for animals; Mr. Lewis Chancellor, well-known hunter, personally collected several duikers and water chevrotains. Mr. and Mrs. George Blowers, of the Bank of Monrovia, presented their household pets, a red duiker, a civet cat, and a linsang. To all of these the expedition is under deep obligation.

The other specimens were collected almost entirely by natives in various parts of the country, and many were brought back by the party on its field trips.

In addition to the live animals a considerable collection of alcoholic specimens was made, including fishes, reptiles, batrachians, and insects. All preserved specimens collected on this expedition are being turned over to the United States National Museum.

At the close of the fiscal year the expedition was still in the field, although a preliminary shipment had been made from Liberia to Boston in the care of Roy J. Jennier, who arrived at that port on May 17, 1940. A summary of the specimens in this shipment follows:

Class	Species	Individuals
Mammals	5	13
Birds	8	15
Reptiles	11	53
Mollusks	1	14
Total	25	95

Some of these animals were placed on display in the exhibition of the Firestone Tire & Rubber Co. at the New York World's Fair, upon the close of which they will be forwarded to Washington. The remainder were brought direct to Washington.

The other members of the expedition sailed from Monrovia on July 15, 1940, and arrived at Norfolk, Va., August 6 with about 100 specimens including 2 pigmy hippopotami, dwarf civets, crested monkey-eating eagles, the rare Liberian ratel, and other little-known species. A list of the live animals which arrived in Boston on May 17, follows:

SMITHSONIAN-FIRESTONE EXPEDITION

Scientific name	Common name	Number
Python sebae	African rock python	2
Amyda triunguis	West African soft-shelled turtle	1
Kinixys erosa	West African hinged tortoise	25
Naja sp	Cobra	4
Varanus niloticus	African monitor	5

SMITHSONIAN-FIRESTONE EXPEDITION—continued

Scientific name	Common name	Number
Bitis nasicornis	Rhinoceros viper	8
Bitis gabonica	Gaboon viper	3
Osteolaemus tetraspis	Broad-nosed crocodile	1
Atheris chlorechis	West African tree viper	1
Pelusios derbianus	Turtle	3
Atilax pluto	West African water civet	2
Perodicticus potto	Potto	1
Cricetomys gambianus	Gambia pouched rat	4
Pan satyrus	Chimpanzee	2
Cercocebus fuliginosus	Sooty mangabey	4
Stephanoaetus coronatus	Crowned hawk eagle	1
Kaupifalco monogrammicus	Northern lizard-buzzard	2
Astur tachiro macroscelides	West African goshawk	1
Milvus migrans parasitus	African yellow-billed kite	1
Tympanistria tympanistria fraseri	Tambourine dove	6
Columba guinea	Triangular spotted pigeon	1
Streptopelia semitorquata	African red-eyed dove	2
Ceratogymna elata	Yellow-casqued hornbill	1
Achatina achatina	Giant land snail	14

SOUTHERN ASIATIC EXPEDITION

On July 8, 1939, Malcolm Davis returned from Calcutta, India, where he had gone to bring back the first Indian rhinoceros that this institution had ever had. This was collected for the Park by the Government of Assam, British India, through the interested offices of the United States Consul General, Dr. J. C. White. It arrived in Washington in perfect condition and may be considered one of the "stars" of the collection. Mr. Davis took with him a few North American animals which were turned over to zoos in the East; in return he received a number of interesting specimens. In Calcutta he was given friendly assistance by Sir David Ezra, the noted bird fancier. A complete list of the specimens obtained on this trip follows:

SOUTHERN ASIATIC EXPEDITION

Scientific name	Common name	Number
Rhinoceros unicornis	Great Indian one-horned rhinoceros	1
Macaca sinica	Toque or bonnet monkey	3
Macaca mulatta	Golden rhesus	2
Presbytis entellus pallipes	Ceylon gray langur	4
Presbytis seneæ nestor	Western purple-faced monkey	2
Ratufa macroura dandolena	Grizzled giant squirrel	2
Felis chaus	Jungle cat	1
Viverricula indica rasse	Small civet	1
Alectoris graeca	Chukar partridge	12
Gallus lafayetti	Ceylonese jungle fowl	2

SOUTHERN ASIATIC EXPEDITION—continued

Scientific name	Common name	Number
Threskiornis melanocephala	Black-headed ibis	4
Streptopelia chinensis ceylonensis	Ash dove	12
Munia maja	White-headed munia	3
Munia punctulatus	Rice bird or nutmeg finch	2
Munia molucca	Black-throated munia	10
Diardigallus diaridi	Siamese fireback pheasant	1
Anthropoides virgo	Demoiselle crane	6
Gavialis gangeticus	Indian gavial	3
Crocodilus palustris	"Toad" crocodile	2
Varanus salvator	Monitor lizard	1
Testudo elegans	Star tortoise	6
Naja naia	Common cobra	4
Trimeresurus trigonocephalus	Green pit viper	2
Vipera russelli	Russell's viper	2
Dendrophis bifrenalis	Green tree snake	4
Dryophis mycterizans	Asiatic whip snake	8
Ptyas mucosus	Indian rat snake	4
Kachuga tectum	Spotted-bellied tortoise	7
Trionyx punctata punctata	Asiatic soft-shelled turtle	3
Geoclemys hamiltoni	Small spotted turtle	1
Morenia ocellata	Turtle	10
Python molurus	Indian python	6

ANTARCTIC AND SOUTH AMERICAN EXPEDITION

At the invitation of the United States Antarctic Exploration Service to send a representative from the Zoo, Malcolm Davis, Principal Keeper of the National Zoological Park, sailed from Boston on the M. S. *North Star* November 11, 1939, with Admiral Byrd and other members of the exploration party that was going to the Antarctic to establish bases on that continent. Mr. Davis assisted in the unloading of the ship at the West Base and obtained some specimens including an emperor penguin, which was shipped from Valparaiso, Chile, and arrived in Washington March 5, 1940, having been brought through the Tropics in the cold-storage room of a passenger vessel.

Other specimens were left at Valparaiso while Mr. Davis remained aboard the *North Star*, which went back to establish the East Base. Here additional specimens were obtained, and Mr. Davis finally sailed from Valparaiso on the Grace Line vessel *Santa Maria*, which arrived at New York April 25, 1940. He brought with him a crab-eating seal, probably the first to be brought north of the Equator, and a group of Adelie penguins. These penguins, together with the emperor penguin, were kept in the glass-fronted cold room in the bird house, where they enjoyed a temperature of 56°. However, crushed ice was also put into the cage, and it was interesting to note that the Adelie penguins would stand for hours on the crushed ice in a temperature of 56°.

Additional specimens were obtained at Valparaiso and other points along the west coast of South America. A complete list of those brought to Washington follows:

ANTARCTIC AND SOUTH AMERICAN EXPEDITION

Scientific name	*Common name*	*Number*
Aptenodytes forsteri	Emperor penguin	1
Pygoscelis adeliae	Adelie penguin	13
Caiman sp	Caiman	1
Parabuteo unicinctus	Hawk	1
Notiopsar curaeus	Chilean blackbird	16
Phrygilus fruticeti	Mourning finch	6
Phrygilus gayi	Gay's gray-headed finch	8
Sicalis luteola	Misto finch	8
Spinus uropygialis	Chilean siskin	11
Diuca diuca	Diuca finch	20
Zonotrichia capensis	Chingolo	6
Trupialis miliaris	Military starling	8
Gallus sp	Araucanian fowl	4
Turdus rufiventris	Argentine robin	2
Molothrus sp	Cowbird	1
Zenaida auriculata	South American mourning dove	15
Cerchneis sparverius cinnamominus	Chilean sparrow hawk	2
Milvago chimango	Chimango	1
Belanopterus chilensis	Chilean lapwing	2
Paroaria cucullata	Brazilian cardinal	9
Cyanocorax mystacalis	Moustached jay	1
Potos flavus	Kinkajou	3
Cebus capucinus	White-throated capuchin	1
Felis glaucula	Margay	1
Sula sp	Booby	1
Lobodon carcinophaga	Crab-eating seal	1
Marmosa elegans	Murine opossum	1
Felis concolor puma	Patagonian puma	1
Dusicyon sp	South American fox	1

GIFTS

The receipt of specimens as gifts continues to be a main source of supply to the collection. Acknowledgment is made in a complete list of donors and their gifts. Among interesting additions were a pair of black bears from the Pennsylvania Game Commission, obtained through Carl La Barre, of Portland, Pa. Richard Archbold, American Museum of Natural History, New York, N. Y., presented three Finsches' tree kangaroos. A splendid pair of yak was received from the Department of Mines and Resources, Dominion of Canada, through Hoyes Lloyd. From Carlo Zeimet, Washington, D. C., the Park received a group of pheasants including 1 chukar partridge, 7 silver pheasants, 4 golden pheasants, and 12 golden and Lady Amherst hybrids.

DONORS AND THEIR GIFTS

Mrs. R. Adams, Washington, D. C., opossum.
Ross Allen, Silver Springs, Fla., 7 Florida tree frogs, 37 southern green frogs.
Mrs. Maude Anderson, Washington, D. C., 2 mockingbirds.
Richard Archbold, New York, N. Y., 3 Finsches' tree kangaroos.
Kenneth L. Avone, Washington, D. C., 2 white rabbits.
Mrs. Geo. D. Babcock, Washington, D. C., red-tailed hawk.
Mrs. Louise Ballif, Washington, D. C., pekin duck.
Stanley Barriger, Washington, D. C., 2 pekin ducks.
Chas. Baxter, Washington, D. C., nighthawk.
Carl Beale, Washington, D. C., 2 ring-necked pheasants, Formosan ring-necked pheasant, silver pheasant, kangaroo rat, 4 flying squirrels, sparrow hawk.
Dr. Lloyd M. Bertholf, Westminster, Md., 2 Bahama fresh-water turtles.
Jean Biron, Washington, D. C., pekin duck.
Mrs. W. D. Blair, Washington, D. C., weeping capuchin.
Mrs. S. S. Brandenburg, Rockville, Md., white-throated capuchin.
Allen E. Campbell, Washington, D. C., gray fox.
Mrs. B. R. Campbell, Washington, D. C., sparrow hawk.
Canadian Government, Department of Mines and Resources, Wainwright, Alberta, 2 yaks.
Dorothy Carpenter, Washington, D. C., opossum, skunk.
O. H. Clarke, Washington, D. C., coot.
Mrs. C. E. Clift, Washington, D. C., pekin duck.
J. C. Coe, Arlington, Va., 25 prairie rattlesnakes.
Mr. Coffey, Washington, D. C., red-bellied terrapin.
H. James Cole, Bethesda, Md., 9 spotted salamanders, 2 snapping turtles, 5 box turtles, musk turtle, frog, marbled salamander, common newt, painted turtle.
Louis Conradic, Washington, D. C., American ovenbird.
Albert Crampton, Sharpsburg, Md., red-shouldered hawk.
Mrs. L. Cummons, Washington, D. C., Cuban parrot.
Billie Currie, Washington, D. C., sparrow hawk.
Harry Day, Hyattsville, Md., box turtle.
Dessez's Service Station, Washington, D. C., alligator.
Antonio Di Guistino, Washington, D. C., woodchuck or ground hog.
Sergt. A. S. Douglas, No. 10 Police Precinct, Washington, D. C., alligator.
Chas. E. Eaton, Chevy Chase, Md., opossum.
Herbert N. Eaton, Chevy Chase, Md., white and black rat.
Barbara Eckhardt, Washington, D. C., 2 zebra finches.
S. C. Elmore, Alexandria, Va., pekin duck.
Mrs. Belle Evans, Washington, D. C., double yellow-head parrot, flying squirrel.
Sir David Ezra, Calcutta, India, 3 Indian gavials, 12 chukar partridges, 2 golden rhesus monkeys, 2 Ceylon gray langurs, 1 Siamese fireback pheasant, 6 demoiselle cranes, 7 spotted-bellied tortoises, 3 Asiatic soft-shelled turtles, and 1 small spotted turtle.
W. H. Floyd, Arlington, Va., 2 American crows.
P. P. Foster, Bennings, D. C., Cooper's hawk.
Jas. M. Fowler, Washington, D. C., red fox.
Jos. S. France, Washington, D. C., box turtle.
O. M. Freeman, Washington, D. C., water snake.
Mrs. H. L. Freet, Washington, D. C., yellow-naped parrot.
Mrs. Wm. R. Fuchs, Washington, D. C., alligator.

Mrs. Chas. Funk, Washington, D. C., alligator.
Harry E. Gates, Washington, D. C., 2 pekin ducks, diamond-backed terrapin.
Jos. Gaillard, Washington, D. C., sparrow hawk.
Ralph Garett, Henrietta, Tex., 3 horned lizards.
W. C. Giffen, Washington, D. C., white-throated capuchin.
David Gillis, Washington, D. C., red bat.
Richard B. Goetz, Waldorf, Md., 2 red-shouldered hawks.
Marshall Gooding, Kensington, Md., red fox.
Mrs. F. C. Goodwin, Washington, D. C., barred owl.
W. Bart Greenwood, Washington, D. C., jack rabbit, Great Basin pocket mouse, 2 black-eared mice.
Edgar H. Grimes, Washington D. C., 4 tropical fishes.
Curtis G. Guckert, Four Mile Run, Va., American barn owl.
Mrs. B. Hansch, Washington, D. C., raccoon.
R. A. Heindl, Washington, D. C., woodcock.
R. L. Higginbotham, Washington, D. C., 12 tropical fishes.
Chas. Hinton, Washington, D. C., raccoon, toulous goose.
Mr. and Mrs. Gerard Hubbard, Silver Spring, Md., 3 eastern porcupines.
Miss Raye Hudson, Arlington, Va., 4 guinea pigs.
John Bowler Hull, Washington, D. C., 2 screech owls.
Curtis Insley, Cambridge, Md., golden eagle.
Mrs. E. J. Johnson, Washington, D. C., woodchuck or ground hog.
Eunice Johnson, Washington, D. C., grass paroquet.
Mrs. W. Jones, Washington, D. C., 3 cottontail rabbits.
June M. Kern, Washington D. C., screech owl.
Mrs. K. K. Kirkland, Washington, D. C., screech owl.
R. M. Kisner, Washington, D. C., opossum.
Harry Knapman, Silver Spring, Md., red fox.
Vinton K. Lewis, Fairfax, Md., horseshoe crab.
O. M. Locke, New Braunfels, Tex., nine-banded armadillo.
H. A. MacCord, Washington, D. C., large brown bat.
J. M. Marshall, Bluemont, Va., mocking bird.
Edith Martin, Washington, D. C., banded rattlesnake.
Mrs. R. Mays, Washington, D. C., American crow.
Mr. McCullen, Bradbury Heights, Md., alligator.
Mrs. J. C. Meikel, Washington, D. C., 4 grass paroquets.
G. F. Miller, Washington, D. C., yellow-billed cuckoo.
Mrs. W. Miller, Washington, D. C., alligator.
Mrs. Moore, Washington, D. C., 2 mallard ducks.
Mrs. Geo. Murnau, Washington, D. C., white rabbit.
Mrs. R. J. Murphy, Washington, D. C., grass paroquet.
Anthony Muto, Washington, D. C., troupial.
National Institute of Health, through Dr. A. Pachchanian, Washington, D. C., 2 long-tailed mice, 2 northern white-footed mice, 2 Gambel's white-footed mice (albinos), 2 old field mice.
Frank Noell, Washington, D. C., white rabbit.
Mrs. R. Oberst, Washington, D. C., woodchuck or ground hog.
Wm. Orsinger, Washington, D. C., hog-nosed snake.
Parks Department, Charleston, S. C., through A. H. Von Kolnitz, 2 wild turkeys.
T. Patson, Washington, D. C., opossum.
Pennsylvania Game Commission, 2 black bears.
A. R. Peters, Bethesda, Md., pekin duck.
T. A. Petras, Quantico, Va., brown capuchin.

Alan V. Philips, Chattanooga, Tenn., fence lizard.
Chas. Pureus, Washington, D. C., pekin duck.
Capt. W. A. Riedal, U. S. N., Washington, D. C., 2 troupials.
Herman Riegal, Valparaiso, Chile, murine opossum, hawk.
Lowry Riggs, Rockville, Md., 2 jungle fowl.
H. Rinke, Arlington, Va., bald eagle.
S. S. Roberts, Washington, D. C., opossum.
President Franklin D. Roosevelt, The White House, 2 ring-necked doves.
Bernard Rosser, Washington, D. C., 2 alligators.
F. Sanders, Evansville, Ind., rhesus monkey.
Miss Virginia W. Sargent, Washington, D. C., turtledove.
Miss Viola S. Schantz, Washington, D. C., large brown bat.
Jesse P. Schell, Frederick, Md., red fox.
G. M. Schmidt, Frederick Md., red-tailed hawk, barred owl.
Ralph Scott, Washington, D. C., 4 banded rattlesnakes, opossum, 2 black snakes, snapping turtle.
Mrs. W. L. Seibold, Washington, D. C., screech owl.
Mrs. E. E. Sheppard, Washington, D. C., 2 Alaskan frogs.
Shipping Room, W. Bldg., Bureau of Standards, Washington, D. C., weasel.
C. L. Sibley, Wallingford, Conn., 2 melanistic mutant ring-necked pheasants, 2 green Japanese pheasants.
Elsie Simmons, Washington, D. C., alligator.
W. P. Smith, Annapolis, Md., red fox.
Mrs. Stacy, Washington, D. C., alligator.
J. N. Stebbins, Washington, D. C., mourning dove.
Orren Stein, Washington, D. C., 2 pekin ducks.
Mrs. Stovall, Westmoreland Hills, Md., American crow.
Paul Sulcer, Frederick, Md., 8 skunks.
Mrs. W. W. Swaggard, Washington, D. C., yellow-naped parrot.
J. Swanick, Arlington, Va., 2 mallard ducks.
Clifton Taylor, Bladensburg, Md., 2 garter snakes, snapping turtle.
Jack Terry, Washington, D. C., copperhead.
Benny Thomas, Bennings, D. C., Cooper's hawk.
Douglas Tittpoe, Washington, D. C., American crow.
Fred A. Tweed, Jr., Washington, D. C., 5 white rabbits.
U. S. Antarctic Service, emperor penguin, 13 Adelie penguins, crab-eating seal.
U. S. Biological Survey, through Don Spencer, Washington, D. C., 2 meadow mice, 1 jumping mouse, 4 red-backed mice, and 10 pine mice. Through F. C. Lincoln, Washington, D. C., red-shouldered hawk, hybrid duck. Through W. H. Marshall, Boise, Idaho, western porcupine.
Virginia Upton, Lanham, Md., muscovy duck.
Miss Edith Ward, Washington, D. C., ring-necked pheasant, melanistic mutant ring-necked pheasant.
J. W. Warner, Washington, D. C., American crow.
Mrs. C. F. Welch, Washington, D. C., cockatiel.
Dr. A. Wetmore, Washington, D. C., albino purple grackle.
H. G. Wilson, Washington, D. C., American barn owl.
Wilson Teachers College, Washington, D. C., opossum.
Marlene Withone, Washington, D. C., black rabbit.
Norman Yates, Compton, Md., albino opossum.
Carlo Zeimet, Washington, D. C., chukar partridge, 7 silver pheasants, 4 golden pheasants, 12 golden and Lady Amherst hybrid pheasants.

BIRTHS

There were 55 mammals born, 28 birds hatched, and 22 reptiles born or hatched during the year.

MAMMALS

Scientific name	Common name	Number
Ammotragus lervia	Aoudad	4
Axis axis	Axis deer	1
Bibos gaurus	Gaur	1
Bison bison	American bison	5
Bos indicus	Zebu	1
Camelus bactrianus	Bactrian camel	1
Canis lupus nubilus	Plains wolf	3
Canis rufus	Texas red wolf	4
Cervus elaphus	European red deer	1
Choeropsis liberiensis	Pigmy hippopotamus	1
Dama dama	Fallow deer	3
Dolichotis magellanica	Patagonian cavy	4
Felis onca	Jaguar	2
Felis tigris	Bengal tiger	2
Lama glama	Llama	2
Macaca nemistrina	Pig-tailed macaque	1
Magus maurus	Moor monkey	1
Myocastor coypu	Coypu	5
Nasua narica	Coatimundi	5
Petaurus breviceps	Lesser flying phalanger	6
Pseudois nahura	Bharal or blue sheep	1
Taurotragus oryx	Eland	1

BIRDS

Larus novaehollandiae	Silver gull	14
Nycticorax nycticorax naevius	Black-crowned night heron	10
Spheniscus demersus	Jackass penguin	4

REPTILES

Constrictor constrictor	Common boa	10
Cyclagras gigas	Cobra de Paraguay	12

EXCHANGES

A most interesting lot of Asiatic mammals, birds, and reptiles were received from the Zoological Gardens, Colombo, Ceylon. These were brought to the Park by Malcolm Davis of the Zoo staff, along with an Indian rhinoceros, the return of which was the specific reason for his journey to India. The group of animals from Colombo consisted of 7 monkeys of 3 different species, 33 birds of 5 species, and 33 reptiles of 9 different species. An important exchange was made with Louis Ruhe, Inc., New York, N. Y., in which the Park received a splendid pair of bactrian camels. A young has since been born to this pair. Several exchanges have been carried on

with Ennio Arrigutti, Buenos Aires, Argentina, in which the Zoo received a number of desirable South American reptiles. This exchange has been made possible through the cooperation of A. Bienenwald, a member of the crew of the S. S. *Brazil*, who cared for the animals en route. A number of interesting specimens of reptiles that occur in the western part of the United States have been received from C. W. Kern, Tujunga, Calif. A list of the specimens acquired by exchange follows:

EXCHANGES

Scientific name	*Common name*	*Number*
Salamandra salamandra	Fire salamander	25
Hydromantes genei	Salamander	15
Molge vulgaris	European newt	15
	Gray newt	10
Corvus cornix	Hooded crow	4
Vulpes fulva	Red fox	1
Acrochordus javanicus	Elephant-trunk snake	1
Python bivittata	Indian python	1
Gecko gecko	Gecko	9
Camelus bactrianus	Bactrian camel	2
Bombina bombina	Fire-bellied toads	20
Ara macao	Red, yellow, and blue macaw	1
Ceratophrys ornata	Horned frog	4
Hydromedusa tectifera	Snake-necked turtle	6
Liolaemus weigmanni	Lizards	4
Acryllium vulturinum	Vulturine guinea fowl	2
Liophis anomalus	South American brown and yellow striped snake	4
Liophis miliaris	South American brown snake	2
Leimadophis poecilogyrus	South American green snake	1
Phrynops hilarii	Turtle	1
Pseudemys d'orbigni	D'Orbigni's turtle	3
Phyllorhynchus decurtatus perkinsi	Leaf-nosed snake	1
Pituophis catenifer annectens	Western bull snake	2
Lampropeltis getulus boylii	Boyle's king snake	1
Crotalus ruber	Red rattlesnake	1
Crotalus viridis oreganus	Pacific rattlesnake	1
Crotalus cerastes	Sidewinder rattlesnake	2
Arizona elegans occidentalis	Western glossy snake	1
Salvadora grahamiae virgultea	Chaparral patch-nosed snake	1
Sceloporus orcuttii	Orcutt's swift	2
Dipsosaurus dorsalis	Desert iguana	1
Gerrhonotus imbricatus	Plated lizard	2
Phrynosoma blainvillii	California horned lizard	1
Heterodon contortrix	Hog-nosed snake	3
Thamnophis sirtalis	Garter snake	1
Masticophis flagellum	Coachwhip snake	1
Natrix sp	Water snake	1
Clemmys insculpta	Wood tortoise	4
Neotoma floridana	Round-tailed wood rat	5
Pavo cristatus	White peafowl	1
Anserinas semipalmata	Australian pied goose	2

PURCHASES

One of the most important purchases for some time was a Great Indian one-horned rhinoceros obtained from the Forest Department, Government of Assam, India. This was received through the cooperation of United States Consul General J. C. White, Calcutta, India. Other specimens acquired by purchase were four black swans, two Flinders Island wombats, and a South American bush dog. An important lot of South American animals were purchased by Malcolm Davis on the west coast of South America. These were mainly obtained through the kindness and cooperation of Dr. Edwyn P. Reed, of Valparaiso, Chile. A list of the purchases follows:

PURCHASES

Scientific name	*Common name*	*Number*
Pipa americana	Surinam toad	6
Chenopis atrata	Black swan	4
Vombatula ursinus	Flinders Island wombat	2
Pithecia monacha	Saki monkey	2
Callicebus cuprea	Beautiful cebus	1
Aotus trivirgatus	Douroucouli or owl monkey	5
Puntius partipentazona	Red-finned barb	10
Pantodon buchholzi	Butterfly fish	4
Monocirrhus polyacanthus	Leaf fish	4
Tapirus terrestris	South American tapir	1
Icticyon venaticus	Bush dog	1
Epimachus fastuosus	Sickle-billed bird of paradise	1
Parotia sefilata	Six-plumed bird of paradise	1
Acrocodia indica	Asiatic tapir	1
Charina bottae	Rubber boa	1
Calyptocephalus gayi	Gay's frog	8
Micrurus fulvius	Coral snake	1

REMOVALS

DEATHS

Major losses during the year included an emperor penguin, crab-eating seal, Siberian tiger, bush dog, Kodiak brown bear, Kidder's brown bear, and a young chimpanzee. As in the past, all specimens of scientific value that died during the year were sent to the National Museum.

ANIMALS IN COLLECTION THAT HAD NOT PREVIOUSLY BEEN EXHIBITED

MAMMALS

Scientific name	*Common name*
Atilax pluto	West African water civet.
Callicebus cuprea	Red titi monkey.
Dendrolagus inustus finschi	Finsches' tree kangaroo.
Felis chaus	Jungle cat.
Lobodon carcinophaga	Crab-eating seal.
Rhinoceros unicornis	Great Indian one-horned rhinoceros.
Viverricula indica rasse	Small civet.

BIRDS

Aptenodytes forsteri	Emperor penguin.
Epimachus fastuosus	Sickle-billed bird of paradise.
Kaupifalco monogrammicus	Northern lizard-buzzard.
Parabuteo unicinctus	South American hawk.
Pygoscelis adeliae	Adelie penguin.
Tympanistria tympanistria fraseri	Tambourine dove.

REPTILES

Charina bottae	Rubber boa.
Gavialis gangeticus	Indian gavial.
Kachuga tectum	Spotted-bellied tortoise.
Kinixys erosa	West African hinged tortoise.
Liophis anomelis	South American ground snake.
Liophis miliaris	Do.

Statement of Accessions

How acquired	Mammals	Birds	Reptiles	Amphibians	Fishes	Mollusks	Crustaceans	Total
Presented	95	110	119	59	16		1	400
Born	55	28	22					105
Received in exchange	9	9	60	89				167
Purchased	13	6	2	14	18			53
On deposit	16	4	1					21
Received from Smithsonian Institution-Firestone Expedition to Liberia	13	15	53			14		95
Received from Antarctic Expedition	1	14						15
Brought from South America by returning Antarctic Expedition	9	121	1					131
Received from National Zoological Park Expedition to India	16	52	63					131
Totals	227	359	321	162	34	14	1	1,118

Summary

Animals on hand July 1, 1939	2,450
Accessions during the year	1,118
Total animals in collection during year	3,568
Removal from collection by death, exchange, and return of animals on deposit	1,018
In collection June 30, 1940	2,550

Status of Collection

Class	Species	Individuals	Class	Species	Individuals
Mammals	233	704	Insects	1	25
Birds	329	1,071	Mollusks	1	11
Reptiles	148	537	Crustaceans	1	5
Amphibians	26	125			
Fishes	21	67	Total	762	2,550
Arachnids	2	5			

Respectfully submitted.

W. M. Mann, *Director*.

Dr. C. G. Abbot,

Secretary, Smithsonian Institution.

APPENDIX 8

REPORT ON THE ASTROPHYSICAL OBSERVATORY

SIR: I have the honor to submit the following report on the activities of the Astrophysical Observatory for the fiscal year ended June 30, 1940:

These operations are conducted on funds received in part from the appropriation by Congress, amounting for the fiscal year 1940 to $32,070, and in part from private sources. The latter included parts of the income from the Hodgkins and the Arthur funds, and grants for specified objects from John A. Roebling. These private sources contributed altogether $19,000 during the fiscal year.

At Washington, the work is carried on in two old frame buildings south of the Smithsonian Building. There are three mountain stations located in New Mexico, California, and Chile. At these stations, chosen for low winds, high altitude, and extreme cloudlessness, without much regard for living conditions, the principal apparatus is housed within a horizontal tunnel to secure fairly constant temperature conditions. Small dwellings, computing rooms, and garages complete the establishments, which are designed to accommodate only a field director, one assistant, and their families. During the fiscal year a reinforced cement block dwelling has been under erection at the station at Montezuma, Chile, but is not yet fully completed, so that the incommodious frame dwelling there is still occupied.

WORK AT WASHINGTON

Messrs. Aldrich and Hoover, with a force of regular and special computers, some of whom were furnished by W. P. A., continued to work on the complete revision of all results on the solar constant of radiation from all stations and from 1923 to the present time. Many small inconsistencies revealed themselves between results of a single station in different years, and between the results of the different stations in the same year. Each of these inconsistencies was a problem in itself, requiring extensive study, and in some cases extensive remeasurements of photographic records. Consequently, progress was slow in preparing final tables of daily, decadal, and monthly mean values of the solar constant, based on the evidence of all observations. It had been hoped that these results would be ready to assemble and publish early in the calendar year 1940. But at the end of June there still remained several very troublesome questions to be resolved, so that several months more of study seemed indicated.

In the meantime Dr. Abbot has prepared text for volume 6 of the Annals of the Observatory as far as could be done until these revised results were available for discussion. It is believed that when the tables are ready the manuscript can be put in press within 2 months thereafter. Funds for its publication have already been generously furnished by John A. Roebling. The text will explain and illustrate with painstaking fullness the details of the research, and the results will be given with greater completeness than ever before. It may be partially understood what this involves when it is said that the table of daily values of the solar constant is estimated to occupy 144 quarto pages, with three groups of 14 columns each, on every page.

Increasing interest among scientists in these solar-constant studies is apparent. In last year's report attention was called to critical studies of the work published in England. Dr. Abbot's reply, also published there, led to mathematical investigations undertaken at Harvard College Observatory and at the Massachusetts Institute of Technology. Two of these statistical studies have been published by Dr. Theodore E. Sterne, of Harvard. They tend to confirm the reality of periodicities in solar variation, and yield periods for the most part agreeing in length, within the limits of error, with those found by Dr. Abbot and published by him several years ago.[1]

The interest thus aroused led Dr. Shapley, Director of Harvard College Observatory, to invite Dr. Abbot to give six lectures there in May 1940, on the following subjects:

1. Exact measurements of solar radiation.
2. Solar radiation and the atmosphere.
3. The variation of the sun.
4. Weather governed by solar variation.
5. Utilizing solar radiation.
6. Radiation and plant growth.

Serious and sympathetic attention was given to these lectures by the staff of Harvard Observatory and by representatives from the Massachusetts Institute of Technology, the Blue Hill Meteorological Observatory, and elsewhere. After the fourth lecture Dr. Abbot was invited by Dr. Brooks, Director of the Blue Hill Observatory, to publish a summary of the first four lectures relating to meteorology in the Bulletin of the American Meteorological Society. This publication is going forward.

In September 1939 there was held in Washington a Congress of the International Geophysical Union. Among the delegates was the eminent meteorologist, Dr. H. Arctowski, of Poland. His country was conquered and his property lost while the Congress was in session. Later, John A. Roebling provided funds for retaining Dr.

[1] Abbot, C. G., Solar radiation and weather studies. Smithsonian Misc. Coll., vol. 94, No. 10, 1935.

Arctowski on the staff of the Observatory for 1 year, from December 1, 1939. Dr. Arctowski was asked to investigate the relations between solar variation and the weather. At that time he doubted the reality of solar variation as indicated by our observations. But within 2 weeks after beginning his studies, Dr. Arctowski became thoroughly convinced of the reality of solar variation, and that it is the major factor in weather. He has announced these findings in two papers.[2] He is continuing his researches in this field with consuming zeal. It is hoped to retain him another year after the completion of his present engagement.

With the assistance of Miss N. M. McCandlish, special computer under a grant from John A. Roebling, Dr. Abbot has endeavored to evaluate the separate influences produced on weather by the long-range solar periodicities which are referred to above. For this research monthly departures from normal temperature and rainfall for numerous stations in America and other regions were used. It soon appeared that the solar periodicities produce considerable weather changes. But for periodicities of less than 25 months' length, and occasionally for longer ones, shifting of phases in the weather responses took place from time to time. It occurred to Dr. Abbot that these shifts very probably are due to seasonal influences. That is, a solar cause operating in winter might reasonably produce a different phase in its weather effects than the same cause operating in summer. Inasmuch as the solar periodicities are not commensurable with 12 months, their phases of course shift through the seasons. On testing this hypothesis it was found to be sustained by data from many meteorological stations.

It was then recognized that these phase effects might be eliminated by taking into account least common multiples of the several periods as compared individually to 12 months. For instance, an 8-month periodicity returns each 24 months in the same season of the year. Other periodicities recur in the same season at longer intervals. Acting upon this basis we computed the average weather effects over a century or more for 8 solar periodicities ranging in length from 8 months to 68 months in length. Among the stations used were Copenhagen, Vienna, and New Haven, all beginning with the year 1800. It was very encouraging to find that, with the phase taken care of, as explained above, all of these stations agreed in indicating pronounced effects of solar variation, and that there is no indication that a change of phase has occurred in the solar periodicities for over a century. In such long series the solar influences were repeated many

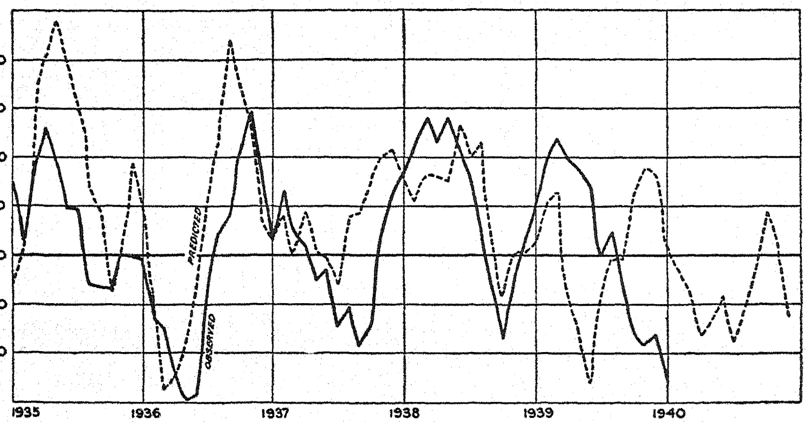
[2] Solar faculae and solar constant variations. Proc. Nat. Acad. Sci., vol. 26, No. 6, pp. 406–411, June 1940.

Researches on temperature changes from day to day and solar constant variations. Bull. Amer. Meteorol. Soc., vol. 21, pp. 257–261, June 1940.

times in the same phase. It was, therefore, possible to obtain from the meteorological records more accurate determinations of the solar periodicities than could be obtained from our solar-constant work of the past 20 years. The three stations mentioned agreed perfectly as to these determinations. In this way we have established the following corrected values for solar periodicities expressed in months:

8.12; 9.79; 11.29; 21.0; 25.3; 39.5; 45¼.

It now became of importance to see whether the average results in departures from normal temperatures and precipitation, corresponding to these corrected periods, could be used synthetically as a means of long-range prediction for the future. In order to investigate this interesting possibility, it was clear that if the courses of the meteorological periodicities used should be determined from records all ante-



PERCENTAGE OF NORMAL PRECIPITATION AT PEORIA, ILLINOIS.
FIVE-MONTH RUNNING MEAN VALUES.

FIGURE 1.

dating 1935, for instance, then it would be honest to regard a synthetic assembly of them, covering the years 1935 to 1940, as a true 5-year prediction, which could be fairly compared with the event. This procedure was undertaken for numerous stations, and for both temperature and precipitation. The resulting forecasts were not all equally successful. But in all cases there was a marked correlation between the forecast and the event. The agreement turned out to be quite as likely to be good in 1940 as in 1935. As an illustration of very good correspondence, though in this instance failing somewhat in 1939, the 5-year forecast and event for the precipitation at Peoria, Ill., is given here. In this case a correlation coefficient of 70±5 percent is found between prediction and event for 58 months. It is hoped that further study may improve the 5-year synthetic forecasts generally. At present they average satisfactory in two-thirds of the months.

WORK IN THE FIELD

As far as weather permitted, daily observations of the solar constant of radiation were continued at three stations: Tyrone, N. Mex., Table Mountain, Calif., and Montezuma, Chile. Criticism having been made again from foreign sources regarding the temperature coefficient of the silver-disk pyrheliometer, numerous redeterminations of this quantity were made at Tyrone and Table Mountain. Owing to a misapprehension of directions, no less than 120 redeterminations were made at Tyrone by Messrs. Moore and Froiland. Their mean is identical with that found previously by Abbot and Aldrich at Washington, and by Zodtner and Greeley at Table Mountain, and is almost identical with that found this year by Butler and Greeley at Table Mountain. Over 200 determinations have now been made, giving as their mean the same temperature correction which has been used for nearly 30 years with silver-disk pyrheliometers. There can now be no further question of altering it.

PERSONNEL

No changes in personnel have taken place since my last report, except that L. A. Fillmen, for 10 years instrument maker under private compensation in the Division of Radiation and Organisms, has been appointed instrument maker under the public funds at the Astrophysical Observatory, succeeding A. Kramer, retired.

Respectfully submitted.

C. G. Abbot, *Director.*

The Secretary,
Smithsonian Institution.

APPENDIX 9

REPORT ON THE DIVISION OF RADIATION AND ORGANISMS

SIR: I have the honor to submit the following report on the activities of the Division of Radiation and Organisms during the year ended June 30, 1940:

As in previous years the Division has been in part supported by a grant from the Research Corporation of New York.

During the past year the Division has continued its active work on problems of photosynthesis and factors affecting plant growth, both from a nutritional and radiation point of view. Dr. McAlister, with the assistance of Dr. Myers, has continued his induction-period studies of photosynthesis with the very valuable addition of simultaneous records of fluorescent intensities. Drs. Johnston and Weintraub have further improved their apparatus and technique in carrying out their investigation of respiration, photosynthesis, and chlorophyll formation as affected by light.

Mrs. Chase has extended her work on the stimulative action of ultraviolet on algae. Dr. Weintraub has completed the initial phases of some of his growth studies and opened up others to be investigated. Mr. Clark has undertaken the construction of an improved and simplified apparatus of his own designing for the accurate and rapid determination of minute amounts of carbon dioxide.

As an outgrowth of the induction-period studies, Dr. Myers is further investigating the relation of the induction behavior of *Chlorella* to the previous condition of culture. In addition, he is planning a comparative study of various methods for the measurement of photosynthesis and of the photosynthetic behavior of various kinds of plants. Mr. Clark and Mr. Fillmen have given valuable assistance in the designing and construction of apparatus. The division library has been improved greatly through the kindness of Mr. Corbin, the Institution's librarian. One hundred and fifteen volumes of periodicals have been bound, and other material has been made more accessible.

PHOTOSYNTHESIS, RESPIRATION, AND CHLOROPHYLL FORMATION

A great many simultaneous measurements of the rate of carbon dioxide uptake and the intensity of fluorescence have been made during the induction period of photosynthesis. The rapid spectro-

graphic method of carbon dioxide measurements previously used has been adapted to a constant-flow technique with a rapid time response. The intensity of fluorescence was measured with a filter-photocell combination.

Experiments so far carried out under a wide range of conditions may be described in terms of two processes. In one, an inverse relationship appears to exist between the rate of carbon dioxide uptake and the intensity of fluorescence. In the other, there is a direct relationship seems to be superimposed.
of wheat seedlings in low oxygen concentration when suddenly exposed to high light intensity. In this case the fluorescence curve shows an abrupt initial rise, a slower secondary rise, and a decay toward the steady state. The simultaneously observed rate of carbon dioxide uptake follows a course inversely related to fluorescence. Thus, when the intensity of fluorescence or rate of carbon dioxide uptake are plotted against time, the two curves are almost perfect mirror images (as to time). For wheat in normal oxygen concentration, the mirror-image relationship is less perfect, and a direct relationship seems to be superimposed.

The dependence of the direct relationship on oxygen and the observation of a greater rate of carbon dioxide uptake in low oxygen suggests that this process involves a photooxidation. In the alga *Chlorella pyrenoidosa* the induction behavior is greatly influenced by the previous conditions of culture. Cells grown in 4 percent carbon dioxide show a response comparable to that of wheat. When the cells are acclimated to air of 0.03 percent carbon dioxide the photooxidation type of response predominates.

Further and more quantitative work is being undertaken along this line, for it is felt that fluorescence in these experiments is a useful tool in the study of the mechanism of photosynthesis.

Preparatory to other experiments on photosynthesis, respiration and chlorophyll studies have been continued with the recording spectrographic carbon dioxide apparatus. Attention was especially directed to detecting any difference in respiration of etiolated barley seedlings that might occur in a change from darkness to light of low intensities. As has been pointed out in other reports, this information is essential in the measurement of photosynthesis as determined by gaseous exchange. Repetition of these experiments indicated a slight increase in the rate of respiration when the plants were illuminated. However, the rates of respiration were different on successive periods so that it was necessary to look for possible sources of error. It was found that etiolated seedlings placed in the growth chamber connected with the carbon dioxide measuring apparatus did not become green in a normal manner. The amount of chlorophyll formed was 20 to 30 percent lower than in a control chamber not connected with the ap-

paratus. The difficulty was traced to a minute amount of mercury vapor entering the growth chamber from the mercury seal of the air-circulating pump.

The problem then resolved itself into one of obtaining a properly designed circulating pump for the carbon dioxide measuring apparatus. In a closed system of this type it is necessary to circulate the air in a system absolutely leakproof to carbon dioxide. Even the slightest amount, a few cubic millimeters, would introduce an error that would invalidate the measurements made by this method.

A metal bellows-type pump was constructed and installed. This worked fairly well but carried with it certain disadvantages. A third type of pump making use of a rotating magnetic field was next tried, but was discarded because of its lack of power. A fourth pump was constructed and, from the few preliminary experiments so far tried, it is believed that it will meet the rigid requirements of this exacting experimentation.

A series of experiments on etiolated barley seedlings clearly shows that there is enough chlorophyll formed in 1½ hours' exposure to light of about 100 foot-candles to be easily measured.

The instrumental phases and the perfecting of experimental technique have now been completed to the point where work on the problems relating to the genesis of chlorophyll and the beginning of photosynthesis may be carried on in greater detail.

PLANT GROWTH INVESTIGATIONS

PLANT HORMONES AND CHEMICAL FACTORS

A standardized technique has been worked out for the extraction of growth substances from the oat seedling and, in a comparative study of the various methods employed by other investigators, has been found to possess a number of advantages. It is becoming more generally appreciated among the workers in this field that the problem of growth substance assay is greatly complicated by the possible existence of hormone precursors, of active and inactive forms of the growth substance itself, and of growth inhibitors. A complete understanding of the behavior of the plant must take all these factors into account and further work is now being done along these lines.

In the study of the growth of excised oat shoots and leaves a number of biochemical substances, several of which have been made available through the generosity of Merck & Co., as well as various plant extracts, have been tested. As yet it has not been possible to develop an artificial environment which will enable the excised organs to develop in an entirely normal manner, but some interesting interrelationships among the various parts of the plant have come to light. These studies are being continued.

RADIATION EFFECTS

The initial phase of the study of the spectral sensitivity of the oat mesocotyl has now been completed. The general finding, which is expected to be published shortly, is that this organ shows its maximum light sensitivity in the red region of the spectrum and decreased response at shorter or longer wave lengths. This is especially interesting since it is very different from the spectral sensitivity of the contiguous organ of the oat seedling, the coleoptile, as demonstrated in growth and phototropism. The diversity of behavior raises several problems with respect to the mechanism of the light effect which are now being investigated. One of these concerns the nature of the photoreceptive pigment involved. It has been possible to demonstrate the presence, in dark-grown oat seedlings, of a pigment which appears to have the requisite absorption spectrum. Its spectral properties correspond with those recorded in the literature for protochlorophyll. However, because of the incomplete and contradictory nature of the data in the literature, it seems desirable to undertake an extensive investigation of the whole protochlorophyll problem.

A further result of the study is that the magnitude of the light effect is proportional to the logarithm of the light intensity. This fact suggests the possibility that more than one photochemical reaction is involved. It is hoped to pursue this problem also.

Experiments on the stimulation effects of ultraviolet radiation on the multiplication of cells of the green alga *Stichococcus bacillaris* Naeg. have been continued during the past year. Four seccessive exposures of the algal cells were made to stimulative amounts of each of the wave lengths 2352, 2483, and 2652 A. After each exposure the growth rate (expressed as number of cells) increased until at the conclusion of the fourth exposure it was 4 to 4.8 times that of the control cultures. Cells irradiated with the optimum stimulative exposure of 2967 A. increased at a rate of 1.5 to 1.6 times the control in the first exposure; but after the second exposure the rate of muliplication of cells was similar to that of the controls. The stimulated cells diminished in length with each successive exposure. They increased slightly in width after the first two exposures, then decreased with the next two exposures so that after the fourth and final exposure, the cells were less wide than those of the controls. Numerous disintegrated cells were present in the cultures that had been exposed three and four times when they were examined 2 to 3 months after the final exposure, whereas the cells exposed only twice appeared to be a darker green and more healthy than the controls. The sum of the three optimum dosages given to the algae was twice that of the lethal quantity.

Cultures of stimulated algae when exposed to lethal intensities of the full ultraviolet spectrum proved to be less sensitive to the lethal amounts than were the control cells. Even those cultures that had been stimulated by four successive exposures and which contained numerous disintegrated cells were less sensitive to the lethal amounts than were the control cells.

A detailed account of this research will be published under the title "Increased Stimulation of the Alga *Stichococcus bacillaris* by Successive Exposures to Short Wave Lengths of the Ultraviolet."

PERSONNEL

Dr. Jack E. Myers was granted a National Research Fellowship to carry on his research in photosynthesis in the Division's laboratory. This fellowship, which began September 19, 1939, has been renewed for a second year.

L. A. Fillmen, by an executive order, was appointed to the civil service on May 20, 1940, and transferred to the staff of the Astrophysical Observatory as instrument maker.

PAPERS PRESENTED AT MEETINGS

Cultivation of excised oat leaves. Presented by Robert L. Weintraub before the American Society of Plant Physiologists, Columbus, Ohio, December 28, 1939.

Induction and related phenomena. Presented by E. D. McAlister at the symposium on photosynthesis, Section C (Chemistry) of the American Association for the Advancement of Science, Columbus, Ohio, December 28, 1939.

Plant tissue cultures. Presented by Robert L. Weintraub before the Botanical Society of Washington, D. C., March 5, 1940.

Sensitivity of plants with special reference to light. Presented by Earl S. Johnston before the Gamma Alpha Scientific Fraternity, The Johns Hopkins University, Baltimore, Md., April 5, 1940.

Time course of photosynthesis and fluorescence. Presented by E. D. McAlister before the Physiological Colloquium, Washington, D. C., June 10, 1940.

PUBLICATIONS

Johnston, Earl S., and Weintraub, Robert L. The determination of small amounts of chlorophyll—apparatus and method. Smithsonian Misc. Coll., vol. 98, No. 19, pp. 1–5, 1939.

Meier, Florence E. Stimulative effect of short wave lengths of the ultraviolet on the alga *Stichococcus bacillaris*. Smithsonian Misc. Coll., vol 98, No. 23, pp. 1–19, 1939.

Johnston, Earl S. Sunlight and plant life. Scientific Monthly, vol. 50, June, pp. 513–525, 1940.

Respectfully submitted.

Earl S. Johnston, *Assistant Director.*

Dr. C. G. Abbot,

Secretary, Smithsonian Institution.

APPENDIX 10

REPORT ON THE LIBRARY

SIR: I have the honor to submit the following report on the activities of the Smithsonian Library for the fiscal year ended June 30, 1940:

THE LIBRARY

The library—or, more correctly, the library system—has come into being, unit by unit, as the interests and needs of the Smithsonian have developed. The main unit, dating from 1846, the year of the establishment of the Institution, was transferred in 1866 to the Library of Congress, where, as the Smithsonian Deposit, it has since grown steadily by frequent sendings from the library of the Institution. It is notable for the completeness of its collections of scientific and technological publications, especially those of learned institutions and societies. Other important units of the system are the libraries of the United States National Museum and the Bureau of American Ethnology; still others are those of the Astrophysical Observatory, Freer Gallery of Art, National Collection of Fine Arts, National Zoological Park, Division of Radiation and Organisms, the Langley Aeronautical Library, and the Smithsonian Office Library. The system also includes the 35 sectional libraries of the National Museum, which are the immediate working tools of the curators and their assistants.

PERSONNEL

The staff remained, for the most part, unchanged. Miss Marie Ruth Wenger, library assistant, was promoted to the grade of junior librarian. The assistant messenger, Roland O. J. Caraccio, resigned in June. Many of the W. P. A. employees of the year before, with a few others more recently added, were assigned to the library until the close of the Smithsonian project in April. Their service was highly appreciated.

EXCHANGE OF PUBLICATIONS

The exchange work of the library was, of course, seriously interfered with by the abnormal economic and political conditions in several parts of the world. As the year advanced, it became increasingly difficult to carry on the customary exchange of publications with societies and institutions abroad. In not a few cases, foreign

publications were issued less frequently than usual, suspended for the time being, or discontinued altogether. In most instances, those that came at all were very late in arriving. Some even were lost in transit. This irregularity and uncertainty put the library to its extreme effort to obtain, before it was too late, all the publications it could of those needed in the work of the Institution. In this it was only moderately successful. The packages it received through the International Exchange Service, for example, numbered 1,329—fewer by 865 than those received the previous year. There was also a falling off—of more than 2,000—in the packages that came by mail. This decrease is ominous, for while it may be possible, in various ways, after the wars are over and conditions become more normal, to fill many of the gaps in the foreign series, probably some will remain unfilled.

Most of the large sendings were received early in the year, while world conditions were still fairly stable. They were from the Berliner Gesellschaft für Anthropologie, Ethnologie und Urgeschichte, Berlin; Yenching University, Peiping; Reale Società Geografica Italiana, Rome; Biblioteca Nazionale Centrale di Firenze, Florence; International Institute of Intellectual Cooperation, Paris; Academia Română, Bucharest; Royal Society of Queensland, Brisbane; Royal Society of New South Wales, Sydney; Manx Museum, Douglas; G. W. R. Swindon Engineering Society, Swindon; Pan-Pacific Union, Honolulu; Pomona College, Claremont; and Florida Entomological Society, Gainesville. These sendings were for the Smithsonian Deposit and the libraries of the National Museum and Freer Gallery of Art.

There was, as would be expected, even a worse falling off in the dissertations received, especially from foreign institutions. There were only 1,608 of these, as against 5,190 the year before. They came from the universities of Basel, Berlin, Bern, California, Freiburg, Giessen, Greifswald, Louvain, Lund, Lwow, Lyon, Neuchâtel, Pennsylvania, Strasbourg, and Warsaw, and the technical schools of Braunschweig, Delft, Dresden, Karlsruhe, and Zürich. Of the dissertations, 788 were assigned to the Smithsonian Deposit, and the others, on account of their subject matter, to the library of the Surgeon General.

The staff wrote 2,502 letters, most of which had to do with the library's exchange work—an increase of 212 over the previous year. There was also an increase of 57 in the number of new exchanges arranged for and of 157 in the number of want cards handled, in connection with the special effort of the staff to satisfy the needs of the Smithsonian libraries, either by exchanging publications or by drawing liberally on the large collection of duplicates lately made available at the Institution. The number of publications thus obtained

was 7,546, or 1,789 more than in 1939. It should be made clear, however, that a great many of these items were taken from the surplus stock mentioned above and were used by the libraries, particularly the Smithsonian Deposit and the library of the National Museum, in building up second or reserve sets. Other libraries of the system, especially those of the Astrophysical Observatory, National Collection of Fine Arts, Radiation and Organisms, and National Zoological Park, also benefited generously from this activity of the staff. It is expected that the libraries will benefit even more richly in the year to come from the thousands of publications that will be offered to them from the same surplus collection.

In the interest of the exchange work, too, it may be noted that during the past fiscal year many publications of the Institution and its bureaus were returned to the library from various colleges, museums, and public libraries throughout the country, and from at least one institution abroad; namely, the Bibliothèque Centrale du Museum National d'Histoire Naturelle, Paris. These publications, which were no longer needed by the institutions that sent them back, were welcomed by the library as they added substantially to the supply of material available for exchange. They also, in a number of instances, brought to the sets in the libraries of the Institution items long out of print and lacking. And, finally, they made it possible for the library to respond favorably to dozens of requests on its waiting list of needs in other libraries. In this clearinghouse activity, as well as in the main exchange work of the year, the library had the cooperation of the offices of publications, and—so far as it was free to function, under the restrictions imposed by the unsettled world conditions—of the International Exchange Service. Among the libraries sharing most generously in this noteworthy enterprise were those of the Department of Agriculture, National Geographic Society, American Bible Society, Marine Biological Laboratory, Woods Hole, Public Museum of the Staten Island Institute of Arts and Sciences, South Dakota State Historical Society, Departamento de Botanica do Estado, São Paulo, Brazil, and the following colleges and universities: Brown, Columbia, Duke, Harvard, Massachusetts Institute of Technology, Mount Holyoke, New York, North Carolina, Oberlin, Pennsylvania, Princeton, Rochester, Vanderbilt, Virginia, William and Mary, and Yale.

GIFTS

The gifts of the year were many. They included 897 publications from the American Association for the Advancement of Science; 653 from the Geophysical Laboratory of the Carnegie Institution of Washington; 252 from the American Association of Museums; 216, chiefly on ethnology and archeology, from James

Townsend Russell, Jr.; 100, relating mainly to the natural history of Brazil, from Ernest G. Holt; 23, on airplane engines of various makes, from John E. Rae; and a large number, on miscellaneous subjects, from the Honorable Usher L. Burdick, Member of Congress from North Dakota. Other generous gifts came from members and associates of the Smithsonian staff, notably Secretary Abbot, Assistant Secretary Wetmore, and Mrs. Charles D. Walcott. Among the publications presented by Mrs. Walcott was a highly prized set, in 23 volumes, attractively bound and lettered, of the scientific and other papers, both published and unpublished, of her husband, the late fourth Secretary of the Smithsonian Institution. This will be given a place of honor in the library alongside of similar collected works by Secretaries Henry, Baird, and Langley.

Of the other gifts, only a few, chosen from the large number, can be mentioned here, such as 7 books by Vilhjalmur Stefansson—Hunters of the Great North, The Northward Course of Empire, My Life with the Eskimo, Adventures in Error, My Life with the Eskimos, Unsolved Mysteries of the Arctic, and Iceland the First American Republic—from the author; 5 copies of The Museum in America, in 3 volumes, by Laurence Vail Coleman, from the author, as director of the American Association of Museums; Chinese Jade Carvings of the Sixteenth to the Nineteenth Century in the Collection of Mrs. Georg Vetlesen, in 3 volumes, compiled by Stanley Charles Nott, from Mrs. Georg Vetlesen; Portraits of Shipmasters and Merchants in the Peabody Museum of Salem, and New England Blockaded in 1814 (the Journal of Henry Edward Napier, Lieutenant in H. M. S *Nymphe*)—both edited by Walter Muir Whitehill—from the Peabody Museum; Voyages of the *Valero III*, by De Witt Meredith, from Captain G. Allan Hancock; O. C. Marsh, Pioneer in Paleontology, by Charles Schuchert and Clara Mae Le Vene, from the authors; Les Beaux Arts et les Arts Decoratifs, in 2 volumes, by M. Louis Gonse, from Dr. William Schaus; The Macrolepidoptera of the World, by Adalbert Seitz, from Mrs. Wirt Robinson, the widow of the late Colonel Robinson, professor of chemistry at West Point, who, it will be recalled, was a friend and benefactor of the National Museum; Moss Flora of North America North of Mexico, volume I, part 4, by A. J. Grout, from the author; Communications, volume 10, of the Institut de Géophysique et de Météorologie de L'Université de Lwów, by Dr. Henryk Arctowski, from the author; A Bibliography of Scientific Papers on Climatic Variations, compiled by Dr. Henryk Arctowski, from the Union Géographique Internationale—Commission of Climatic Variations; Science and Social Ethics, by Sir Richard Arman Gregory, from The Friedenwald Foundation; Mouth Infections and

Their Relation to Systemic Diseases—A Review of the Literature, in 2 volumes, by Dr. Malcolm Graeme MacNevin and Dr. Harold Stearns Vaughan, from the authors; Australia, 1788–1938—Historical Review, from the Hon. B. S. B. Stevens, Premier of New South Wales; and Voyage Zoologique d'Henri Gadeau de Kerville en Asie-Mineure (Avril–Mai 1912), Tome Premier, Première Partie (12 copies), from Henri Gadeau de Kerville.

STATISTICS

The accessions to the library system, then, were several thousand fewer than usual. They were as follows:

Library	Volumes	Pamphlets and charts	Total	Approximate holdings June 30, 1940
Astrophysical Observatory	71	95	166	9,845
Bureau of American Ethnology	364		364	[1] 52,762
Freer Gallery of Art	230	94	324	15,761
Langley Aeronautical	33	22	55	3,498
National Collection of Fine Arts	327	198	525	7,292
National Museum	1,867	938	2,805	216,839
National Zoological Park	26	38	64	3,846
Radiation and Organisms	89	2	91	527
Smithsonian Deposit, Library of Congress	1,955	1,214	3,169	566,554
Smithsonian office	129	17	146	30,892
Total	5,091	2,618	[2] 7,709	[2] 907,816

[1] This number includes about 20,000 pamphlets.
[2] From both the accessions for the year and the total holdings are omitted many publications waiting to be completed, bound, or cataloged.

The staff made 26,422 periodical entries; cataloged 6,105 volumes, pamphlets, and charts; prepared and filed 42,388 catalog and shelf-list cards; and loaned 11,745 publications to members of the Institution and its branches. They carried on an extensive interlibrary loan service with more than 50 libraries in Washington and outside, including several in Mexico and Cuba: an undertaking that involved the writing of many letters and the handling—without a single loss, it may be added—of 2,832 publications. They responded to an unusually large number of inquiries for bibliographical and other information, some of which required hours of research, often at the Library of Congress. They also contributed 635 cards to the index of Smithsonian publications, bringing it practically up to date, and a few to the index of exchange relations. Finally, they advanced the union catalog as follows:

Volumes cataloged	3,523
Pamphlets and charts cataloged	2,203
New serial entries made	379
Typed cards added to catalog and shelf list	6,253
Library of Congress cards added to catalog and shelf list	16,504

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SOME OTHER ACTIVITIES

Mention has just been made of two indexes that are in preparation. A third was undertaken late in the year—a card index of the explorations with which the Smithsonian or one of its bureaus has at any time been connected. Both the scientists and the library staff have frequently felt the need of such a file—and to the future historian it will, of course, be of great value. For it will make instantly available the essential facts pertaining to each expedition—for example, dates, places, personnel, scientific results, with exact references to published accounts—taken part in by the Institution since 1846.

Another important piece of work was checking the records for periodical holdings in various libraries of the system, in the interest of the second edition of the Union List of Serials now being prepared.

Still another special task—one that required considerable time on the part of two or three members of the staff, as well as of several W. P. A. employees—was the transfer and rearrangement of the publications that had for years been shelved along the sides of the main hall of the Smithsonian Building, to cases set up in the alcoves at the ends of the hall. In their new locations the most consulted of these collections are more accessible than they were before.

Again, the staff sorted by subject about 3,000 reprints and separates and assigned them to the sectional libraries of the National Museum; added substantially to the card index of auction prices brought by works of art—a project begun the previous year for the library of the National Collection of Fine Arts; nearly completed the inventory of the technological library, with revision of the records as necessary; did further special cataloging for the botanical library; and made notable progress in the library of the Bureau of American Ethnology in eliminating material not pertinent to the work of the Bureau and in reclassifying and rearranging the remaining collections.

And, last but not least, by the joint effort of the staff and the W. P. A. workers the listing of the longer runs of duplicate serials in both the east and west stacks was well advanced. As fast as these lists were finished they were submitted to the libraries of the Institution that they might check the publications they needed. A few of those not wanted were sent to the library of the Department of Agriculture to fill gaps. And many were used in special exchange for other publications required in the work of the Smithsonian.

BINDING

Owing to lack of funds, it was possible to send to the Government bindery only a small proportion of the volumes waiting to be bound. The library of the National Museum sent 714; that of the Astrophysical

Observatory, 50. In addition, however, 241 volumes from several of the libraries, especially that of Radiation and Organisms, were bound by one of the W. P. A. assistants.

NEEDS

Nevertheless, the binding as a whole, already seriously in arrears, fell much farther behind during the year. This is most regrettable, as the plight of the thousands of volumes in question lessens the safety and usability of the serial files. Steps should be taken immediately to remedy this unfortunate condition.

There is great need, too, of more shelf room for the collections, particularly those in the natural history library of the National Museum. At least some temporary provision should be made without further delay for relieving the congestion there, even if no permanent means can be provided at present.

Finally, the staff should be considerably enlarged. Six trained assistants should be added to the regular force at the earliest possible moment. They are an assistant librarian, a junior librarian, a library assistant, a library aid, a messenger, and a typist. These are urgently needed, that the collections, both main and sectional, may be made more fully available and that the libraries of the Institution and its bureaus may, in general, serve more worthily the high purpose to which they are called.

Respectfully submitted.

William L. Corbin, *Librarian.*

Dr. C. G. Abbot,
Secretary, Smithsonian Institution.

APPENDIX 11

REPORT ON PUBLICATIONS

SIR: I have the honor to submit the following report on the publications of the Smithsonian Institution and the Government branches under its administrative charge during the year ended June 30, 1940:

The Institution published during the year 16 papers in the series of Smithsonian Miscellaneous Collections, 1 annual report and pamphlet copies of 27 articles in the report appendix, and 1 special publication.

The United States National Museum issued 1 annual report, 27 separate Proceedings papers, 1 Bulletin, and 1 Contributions from the United States National Herbarium.

The Bureau of American Ethnology issued three bulletins.

Of the publications there were distributed 146,156 copies, which included 56 volumes and separates of the Smithsonian Contributions to Knowledge, 36,872 volumes and separates of the Smithsonian Miscellaneous Collections, 25,266 volumes and separates of the Smithsonian Annual Reports, 3,150 Smithsonian special publications, 65,961 volumes and separates of the National Museum publications, 13,984 publications of the Bureau of American Ethnology, 11 publications of the National Collection of Fine Arts (formerly the National Gallery of Art), 3 publications of the Freer Gallery of Art, 35 reports of the Harriman Alaska Expedition, 16 annals of the Astrophysical Observatory, and 714 reports of the American Historical Association.

SMITHSONIAN MISCELLANEOUS COLLECTIONS

There were issued 2 papers of volume 91, 8 papers and title page and table of contents of volume 98, 5 papers of volume 99, and volume 100 (whole volume), making 16 papers in all, as follows:

VOLUME 91

No. 30. A new cornucopina (Bryozoa) from the West Indies, by Raymond C. Osburn. 3 pp., 2 pls. (Publ. 3584.) March 14, 1940.

No. 31. A new genus and species of eel from the Puerto Rican Deep, by Earl D. Reid. 5 pp. (Publ. 3585.) March 11, 1940.

VOLUME 98

No. 18. Notes on Hillers' photographs of the Paiute and Ute Indians taken on the Powell expedition of 1873, by Julian H. Steward. 23 pp., 31 pls. (Publ. 3543.) July 21, 1939.

No. 19. The determination of small amounts of chlorophyll—apparatus and methods, by Earl S. Johnston and Robert L. Weintraub. 5 pp., 2 pls. (Publ. 3545.) July 31, 1939.

No. 20. The Helt Township (Indiana) meteorite, by Stuart H. Perry. 7 pp., 9 pls. (Publ. 3546.) August 28, 1939.

No. 21. The weekly period in Washington precipitation, by C. G. Abbot and N. M. McCandlish. 4 pp. (Publ. 3547.) July 27, 1939.

No. 22. Birds from Clipperton Island collected on the Presidential Cruise of 1938, by Alexander Wetmore. 6 pp. (Publ. 3548.) August 11, 1939.

No. 23. Stimulative effect of short wave lengths of the ultraviolet on the alga *Stichococcus bacillaris*, by Florence E. Meier. 19 pp., 4 pls. (Publ. 3549.) September 26, 1939.

No. 24. The Ptarmigania strata of the northern Wasatch Mountains, by Charles Elmer Resser. 72 pp., 14 pls. (Publ. 3550.) October 26, 1939.

No. 25. List of the fishes taken on the Presidential Cruise of 1938, by Waldo L. Schmitt and Leonard P. Schultz. 10 pp. (Publ. 3551.) January 4, 1940.

VOLUME 99

No. 1. Sketches by Paul Kane in the Indian country, by David I. Bushnell, Jr. 25 pp., frontispiece. (Publ. 3553.) January 9, 1940.

No. 2. Geologic antiquity of the Lindenmeier site in Colorado, by Kirk Bryan and Louis L. Ray. 76 pp., 6 pls. (Publ. 3554.) February 5, 1940.

No. 3. Ritual ablation of front teeth in Siberia and America, by Aleš Hrdlička. 32 pp., 5 pls. (Publ. 3583.) March 4, 1940.

No. 4. A check-list of the fossil birds of North America, by Alexander Wetmore. 81 pp. (Publ. 3587.) June 18, 1940.

No. 5. The 11-year and 27-day solar periods in meteorology, by H. Helm Clayton. 20 pp. (Publ. 3589.) June 14, 1940.

VOLUME 100

Whole volume. Essays in historical anthropology of North America, published in honor of John R. Swanton in celebration of his fortieth year with the Smithsonian Institution. 600 pp., 16 pls. (Publ. 3588.) May 25, 1940.

The work of John R. Swanton, by A. L. Kroeber. Pp. 1–9.

Introduction, by Julian H. Steward. Pp. 11–13.

Some historical implications of physical anthropology in North America, by T. D. Stewart. Pp. 15–50.

Developments in the problem of the North American Paleo-Indian, by Frank H. H. Roberts, Jr. Pp. 51–116.

The historic method as applied to southeastern archeology, by M. W. Stirling. Pp. 117–123.

Virginia before Jamestown, by David I. Bushnell, Jr. Pp. 125–158, 2 pls.

Problems arising from the historic northeastern position of the Iroquois, by William N. Fenton. Pp. 159–251.

Archeological perspectives in the northern Mississippi Valley, by Frank M. Setzler. Pp. 253–290.

Culture sequence in the central Great Plains, by Waldo R. Wedel. Pp. 291–352, 2 pls.

From history to prehistory in the northern Great Plains, by Wm. Duncan Strong. Pp. 353–394, 6 pls.

Some Navaho culture changes during two centuries (with a translation of the early eighteenth century Rabal Manuscript), by W. W. Hill. Pp. 395–415.

Progress in the Southwest, by Neil M. Judd. Pp. 417–444.

Native cultures of the Intermontane (Great Basin) area, by Julian H. Steward. Pp. 445–502.

Southern peripheral Athapaskawan origins, divisions, and migrations, by John P. Harrington. Pp. 503–532.

Outline of Eskimo prehistory, by Henry B. Collins, Jr. Pp. 533–592, 6 pls.

Bibliography of anthropological papers by John R. Swanton, compiled by Frances S. Nichols. Pp. 593–600.

SMITHSONIAN ANNUAL REPORTS

Report for 1938.—The complete volume of the Annual Report of the Board of Regents for 1938 was received from the Public Printer in December 1939.

Annual Report of the Board of Regents of the Smithsonian Institution showing the operations, expenditures, and condition of the Institution for the year ending June 30, 1938. xiii+608 pp., 115 pls., 71 figs. (Publ. 3491.)

The appendix contained the following papers:

New conception of the universe and of matter, by Gabriel Louis-Jaray.

The nature of the nebulae, by Edwin Hubble.

The sun and the atmosphere, by Harlan T. Stetson.

Cosmic radiation, by P. M. S. Blackett.

A world of change, by Edward R. Weidlein.

Transmutation of matter, by Lord Rutherford.

Science and the unobservable, by H. Dingle.

Some aspects of nuclear physics of possible interest in biological work, by L. A. DuBridge.

Electron theory, by R. G. Kloeffler.

Geology in national and everyday life, by George R. Mansfield.

The floor of the ocean, by P. G. H. Boswell.

Ice ages, by Sir George Simpson.

Soil erosion: The growth of the desert in Africa and elsewhere, by Sir Daniel Hall.

The future of paleontology, by Joseph A. Cushman.

The meteorology of great floods in the eastern United States, by Charles F. Brooks and Alfred H. Thiessen.

Eyes that shine at night, by Ernest P. Walker.

The Chinese mitten crab, by A. Panning.

The biology of light-production in arthropods, by N. S. Rustum Maluf.

The black widow spider, by Fred E. D'Amour, Frances E. Becker, and Walker van Riper.

The language of bees, by K. von Frisch.

Forest genetics, by Lloyd Austin.

The story of the maidenhair tree, by Sir Albert C. Seward.

The water-culture method for growing plants without soil, by D. R. Hoagland and D. I. Arnon.

"Root-pressure"—an unappreciated force in sap movement, by Philip R. White.

The reproduction of virus proteins, by W. M. Stanley.

Modern medicine—the crossroads of the social and the physical sciences, by Charles Austin Doan.

History and stratigraphy in the Valley of Mexico, by George C. Vaillant.

The Folsom problem in American archeology, by Frank H. H. Roberts, Jr.

The Roman Orient and the Far East, by C. G. Seligman.

An ancient Chinese capital: Earthworks at Old Ch'ang-an, by Carl Whiting Bishop.

The natural limits to human flight, by H. E. Wimperis.

The historic American merchant marine, by Frank A. Taylor.

Report for 1939.—The report of the Secretary, which included the financial report of the executive committee of the Board of Regents, and which will form part of the annual report of the Board of Regents to Congress, was issued in January 1940.

Report of the Secretary of the Smithsonian Institution and financial report of the executive committee of the Board of Regents for the year ended June 30, 1939. ix+139 pp., 2 pls. (Publ. 3552.)

The report volume, containing the general appendix, was in press at the close of the year.

SPECIAL PUBLICATIONS

Explorations and field-work of the Smithsonian Institution in 1939. 96 pp., 102 halftone figs. (Publ. 3586.)

PUBLICATIONS OF THE UNITED STATES NATIONAL MUSEUM

The editorial work of the National Museum has continued during the year under the immediate direction of the editor, Paul H. Oehser. There were issued 1 annual report, 27 separate Proceedings papers from volumes 85, 86, 87, 88, and 89, 1 Bulletin, and 1 Contributions from the United States National Herbarium, as follows:

MUSEUM REPORT

Report on the progress and condition of the United States National Museum for the year ended June 30, 1939. iii+128 pp. January 1940.

PROCEEDINGS: VOLUME 85

Title page, table of contents, and index. Pp. i–x, 509–530. April 5, 1940.

VOLUME 86

No. 3065. Neotropical flies of the family Stratiomyidae in the United States National Museum, by Maurice T. James. Pp. 595–607, fig. 71. August 3, 1939.

VOLUME 87

No. 3066. Ceratopsian dinosaurs from the Two Medicine formation, Upper Cretaceous of Montana, by Charles W. Gilmore. Pp. 1–18, figs. 1–11. August 3, 1939.

No. 3067. Two new parasitic isopods from the eastern coast of North America, by A. S. Pearse and Henry A. Walker. Pp. 19–23, figs. 12, 13. August 1, 1939.

No. 3068. The Hederelloidea, a suborder of Paleozoic cyclostomatous Bryozoa, by Ray S. Bassler. Pp. 25–91, pls. 1–16, fig. 14. September 12, 1939.

No. 3069. A generic revision of the staphylinid beetles of the tribe Paederini, by Richard E. Blackwelder. Pp. 93–125. September 15, 1939.

No. 3070. New turritid mollusks from Florida, by Paul Bartsch and Harald A. Rehder. Pp. 127–138, pl. 17. September 15, 1939.

No. 3071. A new trematode from the loon, *Gavia immer*, and its relationship to *Haematatrephus fodiens* Linton, 1928, by W. Carl Gower. Pp. 139–143, fig. 15. September 1, 1939.

No. 3072. A study of LeConte's types of the beetles in the genus *Monoxia*, with descriptions of new species, by Doris Holmes Blake. Pp. 145–171, pls. 18, 19. October 5, 1939.

No. 3073. Observations on the birds of northern Venezuela, by Alexander Wetmore. Pp. 173–260. November 3, 1939.

No. 3074. A revision of the soapfishes of the genus *Rypticus*, by Leonard P. Schultz and Earl D. Reid. Pp. 261–270. October 24, 1939.

No. 3075. A taxonomic study of the neotropical beetles of the family Mordellidae, with descriptions of new species, by Eugene Ray. Pp. 271–314, figs. 16–19. December 15, 1939.

No. 3076. Catalog of human crania in the United States National Museum collections: Indians of the Gulf States, by Aleš Hrdlička. Pp. 315–464, fig. 20. May 18, 1940.

VOLUME 88

No. 3078. Trematodes from fishes mainly from the Woods Hole region, Massachusetts, by Edwin Linton. Pp. 1–172, pls. 1–26. May 16, 1940.

No. 3079. Report on certain groups of neuropteroid insects from Szechwan, China, by Nathan Banks. Pp. 173–220, pls. 27–30. April 13, 1940.

No. 3080. *Cestocrinus*, a new fossil inadunate crinoid genus, by Edwin Kirk. Pp. 221–224, pl. 31. March 14, 1940.

No. 3081. Notes on some pedunculate barnacles from the North Pacific, by Dora Priaulx Henry. Pp. 225–236, figs. 1–5. April 30, 1940.

No. 3082. Revision of the chalcid-flies of the tribe Chalcidini in America north of Mexico, by B. D. Burks. Pp. 237–354, figs. 6–14. June 11, 1940.

No. 3083. New genera and species of ichneumon-flies, with taxonomic notes, by R. A. Cushman. Pp. 355–372, figs. 15, 16. March 13, 1940.

No. 3084. The scolytid beetles of the genus *Renocis* Casey, with descriptions of nine new species, by M. W. Blackman. Pp. 373–401, figs. 17, 18. June 22, 1940.

No. 3085. Two new genera and three new species of cheilodipterid fishes, with notes on the other genera of the family, by Leonard P. Schultz. Pp. 403–423, figs. 19, 20. April 26, 1940.

No. 3086. A contribution to the knowledge of the Eucharidae (Hymenoptera: Chalcidoidea), by A. B. Gahan. Pp. 425–458. April 25, 1940.

No. 3087. A review of the parasitic Crustacea of the genus *Argulus* in the collections of the United States National Museum, by O. Lloyd Meehean. Pp. 459–522, figs. 21–47. June 22, 1940.

No. 3088. The ichneumon-flies of the subfamily Neorhacodinae, with descriptions of a new genus and three new species, by R. A. Cushman. Pp. 523–527, fig. 48. April 13, 1940.

No. 3089. Notes on the birds of Kentucky, by Alexander Wetmore. Pp. 529–574. April 23, 1940.

No. 3091. A prehistoric roulette from Wyandotte County, Kansas, by Waldo R. Wedel and Harry M. Trowbridge. Pp. 581–586, figs. 49, 50. June 5, 1940.

VOLUME 89

No. 3092. A revision of the West Indian beetles of the scarabaeid subfamily Aphodiinae, by Edward A. Chapin. Pp. 1–41. May 23, 1940.

BULLETINS

No. 175. Variations and relationships in the snakes of the genus *Pituophis*, by Olive Griffith Stull. vi+225 pp. June 26, 1940.

CONTRIBUTIONS FROM THE U. S. NATIONAL HERBARIUM: VOLUME 28

Part 3. Marine algae of the Smithsonian-Hartford Expedition to the West Indies, 1937, by William Randolph Taylor. Pp. i–iii, 549–562, pl. 20. June 12, 1940.

PUBLICATIONS OF THE BUREAU OF AMERICAN ETHNOLOGY

The editorial work of the Bureau has continued under the immediate direction of the editor, M. Helen Palmer. During the year three bulletins were issued as follows:

Bulletin 101. War ceremony and peace ceremony of the Osage Indians, by Francis La Flesche. vii + 280 pp., 13 pls., 1 fig.

Bulletin 124. Nootka and Quileute music, by Frances Densmore. xxvi + 358 pp., 24 pls., 7 figs.

Bulletin 125. Ethnography of the Fox Indians, by William Jones. Edited by Margaret Welpley Fisher. ix + 156 pp.

REPORT OF THE AMERICAN HISTORICAL ASSOCIATION

The annual reports of the American Historical Association are transmitted by the Association to the Secretary of the Smithsonian Institution and are communicated by him to Congress, as provided by the act of incorporation of the Association.

The report for 1935, volume 2 (Writings on American History) and the report for 1938 (Proceedings) were issued during the year. The report for 1936, volume 2 (Writings on American History, 1936) and the report for 1937, volume 2 (Writings on American History, 1937–1938) were in press at the close of the year.

REPORT OF THE NATIONAL SOCIETY, DAUGHTERS OF THE AMERICAN REVOLUTION

The manuscript of the Forty-second Annual Report of the National Society, Daughters of the American Revolution, was transmitted to Congress, in accordance with law, December 11, 1939.

ALLOTMENTS FOR PRINTING

The congressional allotments for the printing of the Smithsonian Annual Reports to Congress and the various publications of the Government bureaus under the administration of the Institution were virtually used up at the close of the year. The appropriation for the coming year ending June 30, 1941, totals $73,000, allotted as follows:

Smithsonian Institution	$15,000
National Museum	30,250
Bureau of American Ethnology	11,150
National Collection of Fine Arts	400
International Exchanges	100
National Zoological Park	100
Astrophysical Observatory	400
American Historical Association	7,100
Total	64,500
Reserve	8,500
Grand total	73,000

Respectfully submitted.

W. P. True, *Chief, Editorial Division.*

Dr. C. G. Abbot,
Secretary, Smithsonian Institution.

REPORT OF THE EXECUTIVE COMMITTEE OF THE BOARD OF REGENTS OF THE SMITHSONIAN INSTITUTION

FOR THE YEAR ENDED JUNE 30, 1940

To the Board of Regents of the Smithsonian Institution:

Your executive committee respectfully submits the following report in relation to the funds of the Smithsonian Institution, together with a statement of the appropriations by Congress for the Government bureaus in the administrative charge of the Institution.

SMITHSONIAN ENDOWMENT FUND

The original bequest of James Smithson was £104,960 8s, 6d.—$508,318.46. Refunds of money expended in prosecution of the claim, freights, insurance, etc., together with payment into the fund of the sum of £5,015, which had been withheld during the lifetime of Madame de la Batut, brought the fund to the amount of $550,000.

Since the original bequest the Institution has received gifts from various sources chiefly in the years prior to 1893, the income from which may be used for the general work of the Institution.

To these gifts has been added capital from savings on income, gain from sale of securities, etc., and they now stand on the books of the Institution as follows:

Avery, Robert S. and Lydia T., bequest fund	$51, 794. 10
Endowment fund, from gifts, income, etc	255, 037. 25
Habel, Dr. S., bequest fund	500. 00
Hachenberg, George P. and Caroline, bequest fund	4, 081. 70
Hamilton, James, bequest fund	2, 909. 72
Henry, Caroline, bequest fund	1, 227. 52
Hodgkins, Thomas G., fund	146, 675. 45
Parent fund	728, 879. 04
Rhees, William Jones, bequest fund	1, 070. 15
Sanford, George H., memorial fund	2, 003. 51
Witherspoon, Thomas A., memorial fund	130, 982. 00
Special fund	1, 400. 00
Total endowment for general work of the Institution	1, 326, 560. 44

The Institution holds also a number of endowment gifts and other funds, the income of each being restricted to specific use. These are invested and stand on the books of the Institution as follows:

Abbott, William L., fund, bequest to the Institution	$104, 662. 96
Arthur, James, fund, income for investigations and study of sun and lecture on the sun	40, 592. 03

Bacon, Virginia Purdy, fund, for a traveling scholarship to investigate fauna of countries other than the United States	$50,850.81
Baird, Lucy H., fund, for creating a memorial to Secretary Baird	16,132.25
Barstow, Frederic D., fund, for purchase of animals for the Zoological Park	772.05
Canfield collection fund, for increase and care of the Canfield collection of minerals	38,819.63
Casey, Thomas L., fund, for maintenance of the Casey collection and promotion of researches relating to Coleoptera	9,309.42
Chamberlain, Francis Lea, fund, for increase and promotion of Isaac Lea collection of gems and mollusks	28,582.05
Hillyer, Virgil, fund, for increase and care of Virgil Hillyer collection of lighting objects	6,670.62
Hitchcock, Dr. Albert S., library fund, for care of Hitchcock Agrostological Library	1,344.95
Hodgkins fund, specific, for increase and diffusion of more exact knowledge in regard to nature and properties of atmospheric air	100,000.00
Hughes, Bruce, fund, to found Hughes alcove	17,418.53
Myer, Catherine Walden, fund, for purchase of first-class works of art for the use of, and benefit of, the National Gallery of Art	19,239.80
Pell, Cornelia Livingston, fund, for maintenance of Alfred Duane Pell collection	2,449.68
Poore, Lucy T. and George W., fund, for general use of the Institution when principal amounts to the sum of $250,000	78,317.79
Reid, Addison T., fund, for founding chair in biology in memory of Asher Tunis	30,270.38
Roebling fund, for care, improvement, and increase of Roebling collection of minerals	122,488.89
Rollins, Miriam and William, fund, for investigations in physics and chemistry	100,805.06
Smithsonian employees retirement fund	777.80
Springer, Frank, fund, for care, etc., of Springer collection and library	18,201.29
Walcott, Charles D. and Mary Vaux, research fund, for development of geological and paleontological studies and publishing results thereof	11,525.48
Younger, Helen Walcott, fund, held in trust	50,112.50
Zerbee, Francis Brincklé, fund, for endowment of aquaria	772.45
Special research fund, gift, in form of real estate	20,946.00
Total endowment for specific purposes other than Freer endowment	871,062.42

The above funds amount to a total of $2,197,622.86 and are carried in the following investment accounts of the Institution:

U. S. Treasury deposit account, drawing 6 percent interest	$1,000,000.00
Miscellaneous special funds	116,373.61
Consolidated investment fund (income in table following)	1,081,249.25
	2,197,622.86

CONSOLIDATED FUND

Statement of Principal and Income for the Last 10 Years

Fiscal year	Capital	Income	Percentage
1931	$668,069.02	$28,518.07	4.27
1932	712,156.86	26,142.21	3.67
1933	764,077.67	28,185.11	3.68
1934	754,570.84	26,650.32	3.66
1935	706,765.68	26,808.86	3.79
1936	723,795.46	26,836.61	3.71
1937	738,858.54	33,819.43	4.57
1938	867,528.50	34,679.64	4.00
1939	902,801.27	30,710.53	3.40
1940	1,081,249.25	38,673.29	3.47

FREER GALLERY OF ART FUND

Early in 1906, by deed of gift, Charles L. Freer, of Detroit, gave to the Institution his collection of Chinese and other oriental objects of art, as well as paintings, etchings, and other works of art by Whistler, Thayer, Dewing, and other artists. Later he also gave funds for the construction of a building to house the collection, and finally in his will, probated November 6, 1919, he provided stock and securities to the estimated value of $1,958,591.42 as an endowment fund for the operation of the gallery. From the above date to the present time these funds have been increased by stock dividends, savings of income, etc., to a total of $6,112,953.46. In view of the importance and special nature of the gift and the requirements of the testator in respect to it, all Freer funds are kept separate from the other funds of the Institution, and the accounting in respect to them is stated separately.

The invested funds of the Freer bequest are classified as follows:

Court and grounds fund	$684,798.42
Court and grounds maintenance fund	171,963.09
Curator fund	696,897.47
Residuary legacy	4,559,294.48
Total	[1] 6,112,953.46

SUMMARY

Invested endowment for general purposes	$1,326,560.44
Investment endowment for specific purposes other than Freer endowment	871,062.42
Total invested endowment other than Freer endowment	2,197,622.86
Freer invested endowment for specific purposes	6,112,953.46
Total invested endowment for all purposes	8,310,576.32

[1] The greater portion of gain in this capital over previous year is caused by placing on the books of the Institution the approximate market value of a large holding of stock heretofore held at a much lower figure.

CLASSIFICATION OF INVESTMENTS

Deposited in the U. S. Treasury at 6 percent per annum, as authorized in the United States Revised Statutes, sec. 5591		$1,000,000.00
Investments other than Freer endowment (cost or market value at date acquired):		
Bonds (30 different groups)	$539,844.99	
Stocks (41 different groups)	577,792.36	
Real estate and first-mortgage notes	71,661.11	
Uninvested capital	8,324.40	
		1,197,622.86
Total investments other than Freer endowment		2,197,622.86
Investments of Freer endowment (cost or market value at date acquired):		
Bonds (48 different groups)	$2,685,147.75	
Stocks (57 different groups)	3,410,858.25	
Real estate first-mortgage notes	9,000.00	
Uninvested capital	7,947.46	
		6,112,953.46
Total investments		8,310,576.32

CASH BALANCES, RECEIPTS, AND DISBURSEMENTS DURING THE FISCAL YEAR [2]

Cash balance on hand June 30, 1939		$313,097.74
Receipts:		
Cash income from various sources for general work of the Institution	$90,255.92	
Cash gift and contributions expendable for special scientific objects (not to be invested)	41,058.06	
Cash gifts for special scientific work (to be invested)	7.50	
Cash income from endowments for specific use other than Freer endowment and from miscellaneous sources (including refund of temporary advances)	79,627.88	
Cash received as royalties from Smithsonian Scientific Series	35,183.75	
Cash capital from sale, call of securities, etc. (to be reinvested)	126,797.78	
Total receipts other than Freer endowment		372,930.89
Cash income from Freer endowment	242,573.92	
Cash capital from sale, call of securities, etc. (to be reinvested)	1,311,672.25	
Total receipts from Freer endowment		1,554,246.17
Total		2,240,274.80

[2] This statement does not include Government appropriations under the administrative charge of the Institution.

Disbursements:		
From funds for general work of the Institution:		
Buildings—care, repairs, and alterations	$3,118.37	
Furniture and fixtures	114.39	
General administration [3]	34,261.55	
Library	2,112.90	
Publications (comprising preparation, printing, and distribution)	18,574.05	
Researches and explorations	26,477.02	
		$84,658.28
From funds for specific use, other than Freer endowment:		
Investments made from gifts, from gain from sale, etc., of securities and from savings on income	49,621.10	
Other expenditures, consisting largely of research work, travel, increase and care of special collections, etc., from income of endowment funds and from cash gifts for specific use (including temporary advances)	85,677.70	
Reinvestment of cash capital from sale, call of securities, etc.	100,160.14	
Cost of handling securities, fee of investment counsel, and accrued interest on bonds purchased	2,619.75	
		238,078.69
From Freer endowment:		
Operating expenses of the gallery, salaries, field expenses, etc.	45,755.98	
Purchase of art objects	155,214.33	
Investments made from gain from sale, etc., of securities	196,273.55	
Reinvestment of cash capital from sale, call of securities, etc.	1,104,247.02	
Cost of handling securities, fee of investment counsel, and accrued interest on bonds purchased including assessment for employees' retirement system	24,738.29	
		1,526,229.17
Cash balance June 30, 1940		391,308.66
Total		2,240,274.80

[3] This includes salary of the Secretary and certain others.

EXPENDITURES FOR RESEARCHES IN PURE SCIENCE, PUBLICATIONS, EXPLORATIONS, CARE, INCREASE, AND STUDY OF COLLECTIONS, ETC.

Expenditures from general funds of the Institution:		
Publications	$18,574.05	
Researches and explorations	26,477.02	
		$45,051.07
Expenditures from funds devoted to specific purposes:		
Researches and explorations	49,692.55	
Care, increase, and study of special collections	13,453.86	
Publications	3,469.12	
		66,615.53
Total		111,666.60

The practice of depositing on time in local trust companies and banks such revenues as may be spared temporarily has been continued during the past year, and interest on these deposits has amounted to $1,022.34.

The Institution gratefully acknowledges gifts or bequests from the following:

Friends of Dr. Albert S. Hitchcock, for establishment and care of the Hitchcock Agrostological Library.

Firestone Tire & Rubber Co., for expedition to Liberia for the collection of living wild animals.

Research Corporation, further contributions for research in radiation.

John A. Roebling, further contributions for research in radiation.

Mrs. Mary Vaux Walcott, for purchase of certain specimens.

Eleanor E. Witherspoon, for Thomas A. Witherspoon Memorial for the advancement of human knowledge.

All payments are made by check, signed by the Secretary of the Institution on the Treasurer of the United States, and all revenues are deposited to the credit of the same account. In many instances deposits are placed in bank for convenience of collection and later are withdrawn in round amounts and deposited in the Treasury.

The foregoing report relates only to the private funds of the Institution.

The following annual appropriations were made by Congress for the Government bureaus under the administrative charge of the Smithsonian Institution for the fiscal year 1940:

General Expenses (This combines under one heading the appropriations heretofore made for Salaries and Expenses, International Exchanges, American Ethnology, Astrophysical Observatory, and National Collection of Fine Arts of the Smithsonian Institution and for Maintenance and Operation of the United States National Museum.)	$356,620.00
Preservation of collections	628,800.00
Printing and binding	73,000.00
National Zoological Park	237,060.00
Total	1,295,480.00

In addition to the above an appropriation of $270,000 was made in the Third Deficiency Act, 1939, for the installation of an alternating-current electric system in the Smithsonian Institution buildings.

The report of the audit of the Smithsonian private funds is printed below:

SEPTEMBER 24, 1940.

EXECUTIVE COMMITTEE, BOARD OF REGENTS,
Smithsonian Institution, Washington, D. C.

SIRS: Pursuant to agreement we have audited the accounts of the Smithsonian Institution for the fiscal year ended June 30, 1940, and certify the balance of cash on hand, including Petty Cash Fund, June 30, 1940 to be $393,208.66.

We have verified the record of receipts and disbursements maintained by the Institution and the agreement of the book balances with the bank balances.

We have examined all the securities in the custody of the Institution and in the custody of the banks and found them to agree with the book records.

We have compared the stated income of such securities with the receipts of record and found them in agreement therewith.

We have examined all vouchers covering disbursements for account of the Institution during the fiscal year ended June 30, 1940, together with the authority therefor, and have compared them with the Institution's record of expenditures and found them to agree.

We have examined and verified the accounts of the Institution with each trust fund.

We found the books of account and records well and accurately kept and the securities conveniently filed and securely cared for.

All information requested by your auditors was promptly and courteously furnished.

We certify the Balance Sheet, in our opinion, correctly presents the financial condition of the Institution as at June 30, 1940.

Respectfully submitted.

WILLIAM L. YAEGER,
Certified Public Accountant.

Respectfully submitted.

FREDERIC A. DELANO,
R. WALTON MOORE,
Executive Committee.

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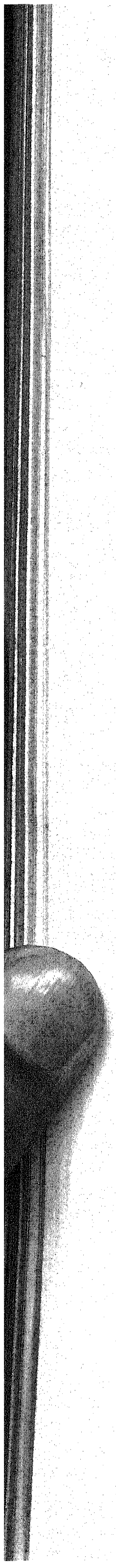
GENERAL APPENDIX

TO THE

SMITHSONIAN REPORT FOR 1940



ADVERTISEMENT

The object of the GENERAL APPENDIX to the Annual Report of the Smithsonian Institution is to furnish brief accounts of scientific discovery in particular directions; reports of investigations made by collaborators of the Institution; and memoirs of a general character or on special topics that are of interest or value to the numerous correspondents of the Institution.

It has been a prominent object of the Board of Regents of the Smithsonian Institution from a very early date to enrich the annual report required of them by law with memoirs illustrating the more remarkable and important developments in physical and biological discovery, as well as showing the general character of the operations of the Institution; and, during the greater part of its history, this purpose has been carried out largely by the publication of such papers as would possess an interest to all attracted by scientific progress.

In 1880, induced in part by the discontinuance of an annual summary of progress which for 30 years previously had been issued by well-known private publishing firms, the secretary had a series of abstracts prepared by competent collaborators, showing concisely the prominent features of recent scientific progress in astronomy, geology, meteorology, physics, chemistry, mineralogy, botany, zoology, and anthropology. This latter plan was continued, though not altogether satisfactorily, down to and including the year 1888.

In the report for 1889 a return was made to the earlier method of presenting a miscellaneous selection of papers (some of them original) embracing a considerable range of scientific investigation and discussion. This method has been continued in the present report for 1940.

SOLAR PROMINENCES IN MOTION[1]

By Robert R. McMath

Director of the McMath-Hulbert Observatory of the University of Michigan

[With 6 plates]

The study of the nearest star to our earth, the sun, is probably of great antiquity. This study, begun by earliest man, has now evolved from the simplest of visual studies and observations into a field of science which demands more and more intricate and expensive apparatus and the services of skilled scientists all over the world. With this evolution has come a separation of the general study into branches. For instance, Dr. C. G. Abbot, of the Smithsonian Institution, is the acknowledged authority on the solar constant, which deals with the radiation received daily by the earth from the sun. Of course, other men at other institutions also study this important aspect of solar phenomena, but their particular branch of specialization may lie in another direction.

At the McMath-Hulbert Observatory, which is located at Lake Angelus, Pontiac, Mich., we are interested most particularly in those solar phenomena which are in some way connected with that part of our sun which we call the chromosphere. This is, perhaps, a loose definition, but we shall use it here for the sake of simplicity.

When one looks at the sun through a piece of heavily smoked glass, he sees what the astronomer calls the photosphere. Surrounding the photosphere is a shell of gas, similar to an atmosphere, which is called the chromosphere. This chromosphere is about 8,000 miles

[1] The ninth Arthur Lecture, given under the auspices of the Smithsonian Institution, January 16, 1940, consisted principally of the unusual motion pictures taken at the McMath-Hulbert Observatory. In all, about 4,000 feet of 35 mm. motion-picture film were shown to the audience, accompanied by comments and explanations by Dr. McMath. This type of lecture does not lend itself readily to reproduction on the printed page, so we publish herewith his general remarks, accompanied by several plates made from the films shown during the lecture. For more information in regard to the instrumentation and the techniques employed, the reader is referred to the Publications of the Observatory of the University of Michigan, with particular reference to vol. 4, pp. 53–73, 1932; vol. 5, pp. 103–117, 1934; vol. 6, pp. 43–44, 1934; vol. 7, pp. 1–56, 1937; and pp. 191–208, 1939. With Dr. Edison Pettit, of the Mount Wilson Observatory, Dr. McMath has published several papers dealing with the scientific aspects of the motion pictures shown at the lecture. These papers have appeared in the Astrophysical Journal, 1937 and 1939, and occasional notes in the Publications of the Astronomical Society of the Pacific.

in depth and is invisible to the naked eye. Arising above the chromosphere, but ordinarily connected to it, we find the solar prominences, the subject of this lecture. The principal instrumentation of the McMath-Hulbert Observatory has been designed and built for the purpose of studying these solar prominences and other related chromospheric phenomena.

At this point it would be well to trace briefly the development of our knowledge of chromospheric phenomena, as each step forward usually rests on the achievements of earlier workers in the field. Because of the fact that the prominences are rarely high enough to subtend an angle as much as 2 minutes of arc, it is not surprising that they apparently were not seen by the early observers of eclipses. In fact, the discovery of the prominences had to await the invention of the telescope. That event occurred early in the seventeenth century, and nearly 100 years later Tannyan, at Berne, Switzerland, reported the chromosphere, which he found by observing an eclipse. Discovery of solar prominences followed shortly thereafter, as Vassenius observed them at an eclipse during the year 1733. These are the most important prephotographic discoveries relating to our subject. It is, of course, impossible to overestimate the importance of the photographic process to science, and to astronomy in particular. Hence we are not surprised that at the eclipse of July 18, 1860, photographs taken 6 minutes apart by Secchi and De la Rue showed that the prominences were moving. Also, by this time the spectroscope had become a new tool in the hands of the scientist, and on August 18, 1868, Janssen observed the bright spectral lines of the prominences at an eclipse. It is of interest to note that at first the bright yellow line of helium was mistaken for sodium. The next day, August 19, 1868, Janssen observed the prominences without an eclipse, by means of a widely opened spectroscope slit. This was indeed an important addition to the available methods of observing the sun. But we should note that it was October 20 of the same year that both Janssen and Lockyer announced this new method.

The next step, and it is a very important step, was the invention of the instrument called the spectroheliograph by an American, George Ellery Hale, in 1892. This instrument appears to have been evolved independently and concurrently by Evershed and Deslandres; perhaps Deslandres may have been about a year later than Hale. Two more years were needed to perfect the spectroheliograph, and for many years it was the principal instrument used for the study of chromospheric phenomena. A few more dates, and our chronology will be sufficiently complete for our purpose here.

In 1931 McMath, at Lake Angelus, started to adapt his technique of practically continuous photography to Hale's spectrohelioscope,

and had obtained successful motion pictures of solar prominences late in 1932. Lyot, a Frenchman, invented and built his coronograph in 1930. His first application of his new instrument to motion-picture photography of solar prominences was in September 1935. And now, a brief description of the solar research at the McMath-Hulbert Observatory may be of interest.

The rotation of the sun as shown by sunspots, the drift of sunspots and their changes, the more active type of solar prominences, showing changes of form, were included in the original work program of the observatory, and a specially designed spectroheliokinematograph for use in motion-picture photography of prominences was constructed in 1931. This spectroheliokinematograph had to be light enough and compact enough to fit on the eyepiece end of a 10½-inch equatorial Cassegrain reflecting telescope, but in spite of these severe restrictions and the relative rarity of active prominences during the sunspot minimum, prominence motions of sufficient interest and complexity to warrant installation of more powerful and versatile equipment for their study were photographed. A tower telescope with pit spectrograph best suited the specifications that we evolved from a study of the prominence motions from the spectrograph films and the then existing instrumentation of the leading solar-research observatories. Accordingly, a tower telescope, embodying our experience in astronomical motion-picture photography and the adaptable features of other tower telescopes, together with innovations leading to ease of control and manipulation, was erected during 1935 and produced its first prominence pictures on July 1, 1936.

With the completion of the new tower, the difficulties encountered with the spectroheliokinematograph have been completely eliminated. The observer may take pictures as rapidly as required, limited only by a minimum effective exposure time of one-fiftieth of a second. The effective wave length of the light producing the picture is under complete control of the observer and may be varied throughout a spectral range of 7,000 angstroms, and any setting may be duplicated to a small fraction of an angstrom. The scale of the picture may be changed in a short time, and the start and end of each exposure are recorded automatically. With the usual type of spectroheliograph, perhaps 150 photographs could be obtained in an 8-hour day; with the McMath-Hulbert tower, 15,000 photographs can be obtained in the same observing time. Although the mechanical features of observing are readily controllable and in a large part automatic, the observer still needs to exercise considerable skill in avoiding too many pictures of a slowly moving object and too few of objects in rapid motion. For the most part, prominence motions

are fairly well represented by taking two pictures per minute. Upon projection, a series of pictures taken at 2 per minute will show motions on the screen which are 720 times faster than in nature. The McMath-Hulbert routine procedure for average objects is to speed up their motions only 360 times. In the pictures shown on the screen the compression factor, or rate of speed-up of the motions, varies from 64 to 360.

It is only because of the great distance to the sun that we need to increase the apparent motions of prominences on the screen by means of time-lapse photography. In terms of terrestrial experience the actual speeds of solar prominence features are enormous. The slowest observable motions are of the order of 1 km. per second, about the same speed as a bullet from a high-powered rifle. The highest observed speed of a prominence feature is about 750 km. per second. Speeds of 10 or 15 km. per second are very common and may be taken as average values.

The accompanying photographs, selected from motion pictures, show, as well as is possible in still pictures, some of the behavior of prominence material. The most outstanding feature of prominence motion, the overwhelming preponderance of motion toward the surface of the sun, obviously cannot be shown; nor can the melee of motions about a sunspot be made clear in any way except by projected motion pictures. These sample photographs have been chosen, in most cases, to emphasize changes in form rather than details of structure, as well as to indicate the importance of obtaining a large number of observations in a short space of time in the investigations of many prominence motions.

A very familiar type of solar photograph is reproduced in plate 1, *A*, which gives the appearance of the surface of the sun on August 18, 1939, showing a number of sunspots of medium size. This is an image of the intensely brilliant photosphere—the surface studied by the earliest visual observers and, except at times of solar eclipses, the only surface available until the advent of the spectroscope. The advantage in the ability to use a selected wave length for observation is seen in plate 1, *B*, a spectroheliogram of the chromosphere taken in the light of the hydrogen line Hα a few moments after the direct photograph *A* was exposed. In this case bright and dark markings in the chromosphere are clearly delineated and serve to indicate features of this higher layer of gases which are transparent to integrated light and, consequently, do not register on a direct photograph. Many of these dark markings or "flocculi" drift across the disk with the rotation of the sun, showing only slight changes over a long period of time. But often, especially in disturbed areas associated with sunspots, a dark flocculus will suddenly burst into

violent activity and break into whiplike filaments, which apparently stream downward into the sun. Spectroheliograms such as plate 1, *C*, which are taken in the light of the broad K line of calcium, emphasize the bright markings and show a mottling of the entire disk which, when projected, has the appearance of a troubled sea. The difference in emphasis of hydrogen and calcium spectroheliograms does not necessarily indicate a separation of the two gases in the chromosphere, for it is possible to record the same features in both spectral lines by proper spectrograph adjustment. This difference does, however, afford a means of selecting certain details for examination by accentuating their appearance above that of surrounding activity. Dark flocculi are more readily photographed in Hα, and, consequently, this line is usually used to record their behavior.

Plate 1, *E*, which is an Hα spectroheliogram of the sunspot group shown in *D* as a direct photograph, was selected from a record of violent chromospheric activity which involved both the bright and dark flocculi. The S-shaped bright flocculus below the large spot very suddenly became more intense and began to expand. At the apparent maximum brilliancy, a dark marking developed along the center line, as shown in the frame reproduced from this point in the record. Eventually, the entire flocculus darkened, disintegrated, and disappeared.

Actually, all details photographed on the disk show a high rate of radiation and appear light or dark depending upon the relationship of their radiation to that of their surroundings. When seen against the disk, the high-level gas clouds, such as surround the spot shown in plate 1, *F*, are dark; but when we follow them to the edge of the sun, as in *G*, they show, in exposures timed to record disk detail, as dimly lighted against the dark background of the sky. In *G* we also can see in profile the general disturbance of the chromosphere in the region of a sunspot. In this position, at the edge of the sun, the high-level formations can be seen and photographed in greater detail, and are called prominences.

Recurrent typical forms and behaviors of motion have been included in Pettit's classification of prominences. More recently, some new types have been revealed by the motion-picture records, and are illustrated by the reproductions in plate 2. The first new type to be discovered was the "coronal," so-called because its apparent origin is somewhere high above the chromosphere in the region of the corona. *A* shows such a streamer at about 150,000 km. above the chromosphere, moving downward toward the sun. This streamer was first barely visible at a higher level, and subsequent spectroheliograms show it moving along a trajectory that terminated in the bright limb at a point above the sunspot. In this picture as well as

in *B*, a neutral density glass flat of 10 percent transmission was introduced to cover the image of the disk, and it enabled us to record some of the surface details while exposing for the faint prominences. The area of intense activity visible in *B* is covered at the limb by a bright mound. This mound form frequently occurs over such regions and has been named a "cap" prominence.

Two subtypes, usually of very short duration, are illustrated in plate 2, *C* and *D* which, in this case, occurred simultaneously over the same sunspot area. These two spectroheliograms are separated in time by only 6.42 minutes between midpoints of exposures. In this short interval the small detached cloud, which is about 31,000 km. above the limb in *C*, has been ejected to a point 79,000 km. above the limb in *D*, and the bright triangular-shaped surge, directly under the ejection in the first scene, has decreased in height from 23,600 to 15,800 km. A typical surge rises from an active area on the chromosphere to its maximum extension and then, apparently with a complete reversal of motion, returns to the surface along the same trajectory. Rarely, at its highest point, a small cloud will be ejected on outward while the main body of the surge subsides. This latter phenomenon is classified as a secondary ejection.

E and *F*, plate 2, represent two stages in the development of a quasi-eruptive prominence. The similarity of this prominence to one strictly classified as active is evident in its general form and the development and motion of its streamers. The eruptive characteristics are illustrated in the later scene, *F*, where the main body of the prominence has been detached from the chromosphere. The motion-picture record reveals that at this stage the velocities of the motions increased, and that the whole prominence began to move along the streamer trajectories. Ultimately, the prominence completely disintegrated, some material moving along streamers to the left, and the major portion entering the chromosphere along the bright streamers at the right. In this case the motion followed paths which had slight curvatures and were, over considerable lengths, nearly parallel to the limb. Of the complete record, the eruptive stage occupies only a small portion and, because of its rapid changes, requires many spectroheliograms to form a continuous story of the behavior.

Many records have depicted the last stages in the history of prominences, but of the early stages very little is known. As yet, we have no means of predicting when, or at what position on the sun, a prominence is about to develop. Therefore, such records as we may have of the beginnings of any type of prominence are the result of particularly good fortune, in that the phenomenon took place in a region under examination.

On September 23, 1938, a detached cloud which existed over a very active area was photographed. During the time that the telescope was directed at this limited portion of the sun's limb, a prominence loop formed and disappeared at the point under examination. Selected spectroheliograms from this record are reproduced in plate 3. The plate covers a period of 2 hours and 20 minutes, and in that short space of time a bright loop rose to a height of 60,500 km., broke at the crest, and fell back into the chromosphere. The brilliance of the loop was remarkable. Up to the time when it began to disintegrate, its intensity was even somewhat greater than that of the adjacent chromosphere. In this case, apparently, the material was carried upward and then returned completely to the active area on the surface from which it had arisen. Except for the displacement of the detached cloud, there remained scarcely a trace of the phenomenon after its rapid subsidence.

Another example of loop formation is found in the record of the sunspot-type prominence of September 7, 1939. Although at certain stages there was a similarity of form and intensity to that of September 23, 1938, the two evidence very different general characteristics. Plate 4 illustrates several stages of the development of the loop of September 7, 1939, from the time *A*, when there was the first faint indication of a small stationary condensation at the right of the main group of streamers, to the time *F*, when the loop had broken up into an intricate pattern of loops and streamers. The phenomenon began as a faint condensation about 42,000 km. above the limb, which suddenly brightened and then extended branches in opposite directions. The branches continued to grow rapidly, and both curved downward, ultimately forming a complete arch. The time occupied by the formation of the arch, as shown in *E*, was 8.27 minutes. The subsequent history of this loop is very different from that of September 23, 1938, which disappeared into the chromosphere. In contrast to this rapid dissolution, the loop of September 7, 1939, continued to develop into more and more small loops and incomplete arches. At all times, prominence material was moving downward from the crests of the loops along both branches to the chromosphere. The appearance of the multiple arches 1 hour and 7 minutes after the loop had completely developed is shown in *F*. This does not, however, represent the final stage, for the phonomenon continued to become more intricate as it gradually lost its extreme intensity. In plate 5 *E*, 2 hours and 2 minutes later than the last stage shown in plate 4, the arches are shown as delicate, beaded filaments.

The prominence in which this arch development occurred is a typical example of the sunspot-type classification which, together

with the sunspot-type prominence of September 21, 1939, is illustrated in plate 5. In both prominences shown, all detectable motions were *downward* along the streamers, and *downward* from the crests of the loops along both branches and into the chromosphere. The relative intensities, or relative densities, of material in different parts of the loops were continually changing while the paths of motion persisted. These prominences exhibited a characteristic gradual increase in height during the time of observation. Because of the great predominance of downward motions, this general growth of the entire phenomenon would seem to be an extension of activity, rather than any sort of material expansion. Plate 5, *A*, *B*, and *C*, are reproductions from the record of September 21, 1939, showing the behavior of a loop formation which measured about 142,000 km. in height and 170,000 km. in width at the beginning of the record, and increased in over-all dimensions about 25 percent during the scene. The changes in relative intensity of different parts of the loop in the 24 minutes which intervened between *A* and *B* are quite evident, and paths of motion 2 hours later are indicated in *C* by the broken streamers.

The prominence of September 7, 1939 (pl. 5, *D*, *E*, and *F*), provided a remarkable motion-picture scene of continuous and varied activity. At the beginning of the record bright knots and delicate streamers cascaded downward 200,000 km. into the sun. As the scene progressed, the general pattern became more intricate, including a background of faint gigantic loops and many small isolated condensations moving at high velocities toward the seething chromosphere. The loop formation previously described occurred during this scene and is illustrated in its later stages in plate 5, *E* and *F*. The scene closed with the longest streamers extending outside the field of the film, reaching somewhere beyond 240,000 km. above the limb.

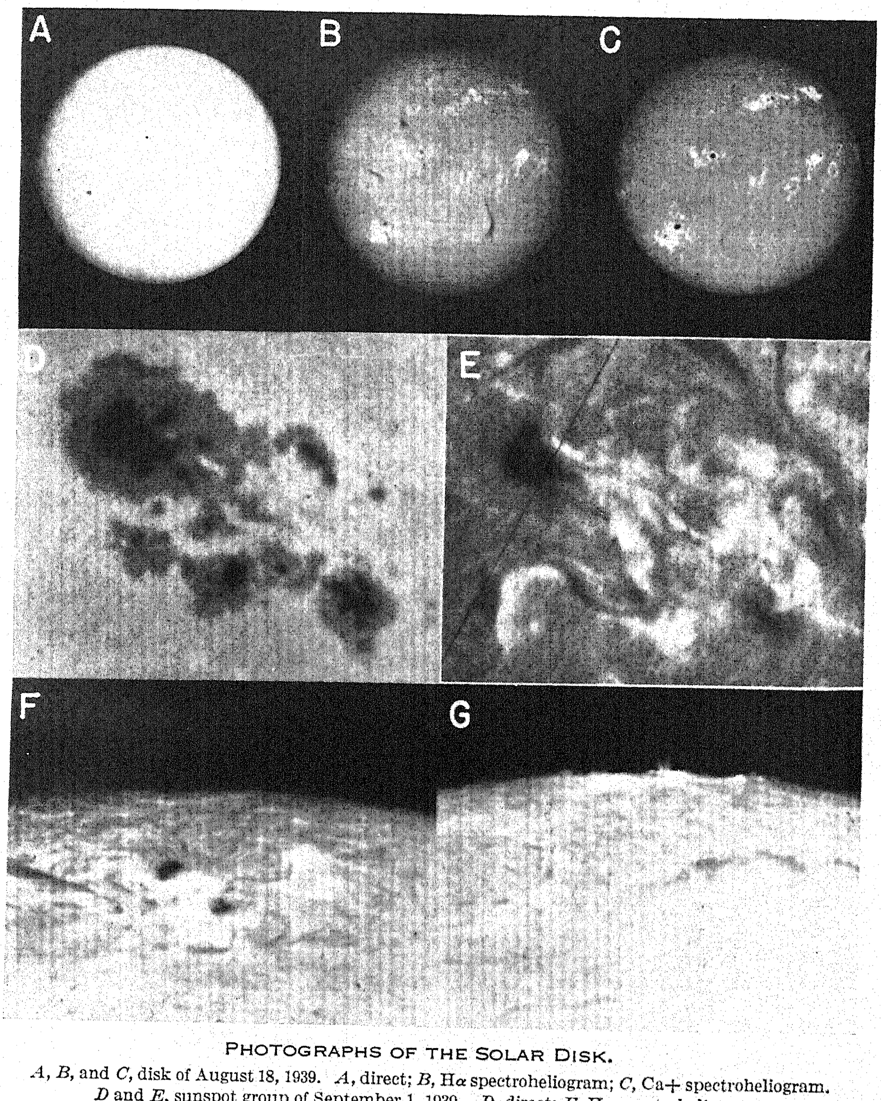
Another very interesting, and perhaps the most impressive, motion-picture scene of prominence activity that we have obtained so far is illustrated in plate 6. This is a record of the quasi-eruptive prominence of August 24 and 25, 1939, photographed in the light of ionized calcium. Throughout the scene the delicate details of the internal prominence structure revealed a surprising activity in the behavior of the motions and the distribution of light intensities. *A* and *B* are reproductions of frames photographed on August 24, 1939, and illustrate the form and dimensions of the prominence in its "active" stage. At this stage the prominence was about 170,000 km. in height and extended even a greater distance along the limb. Not noticeable in the reproduction, but clearly defined from the very beginning of the record, is a narrow "pillar of light" that extends

vertically through the center of the picture, as shown in *A*. This bright area expanded, and another, beginning apparently somewhat nearer the chromosphere, developed to give the light distribution illustrated in *B*.

The start of observations on August 25 found the prominence in the eruptive stage, with the light pattern much more pronounced. In plate 6, *C* and *D*, the localized illumination has the appearance of a searchlight beam, and this impression is enhanced by the prominence material brightening as it moves into the "spotlight" and then leaving its brilliancy behind as it moves on out again. This effect continued until, near the end of the scene, the prominence material had all moved along the streamer trajectories to disappear into the chromosphere. In order to include all the extended activity within the area of the film, the scale of the image was diminished to 50 percent, and later to 15 percent, of the size of the original image. The maximum extension of the prominence was nearly 400,000 km., and it reached a level about 240,000 km. above the sun. This scene illustrates many characteristic motions of quasi-eruptive prominences, and discloses a new phenomenon of light distribution which may prove to be additional evidence in our search for the now hidden reasons for prominence behavior; or, on the other hand, it may prove to be another problem added to the number already involved in the study of solar physics.

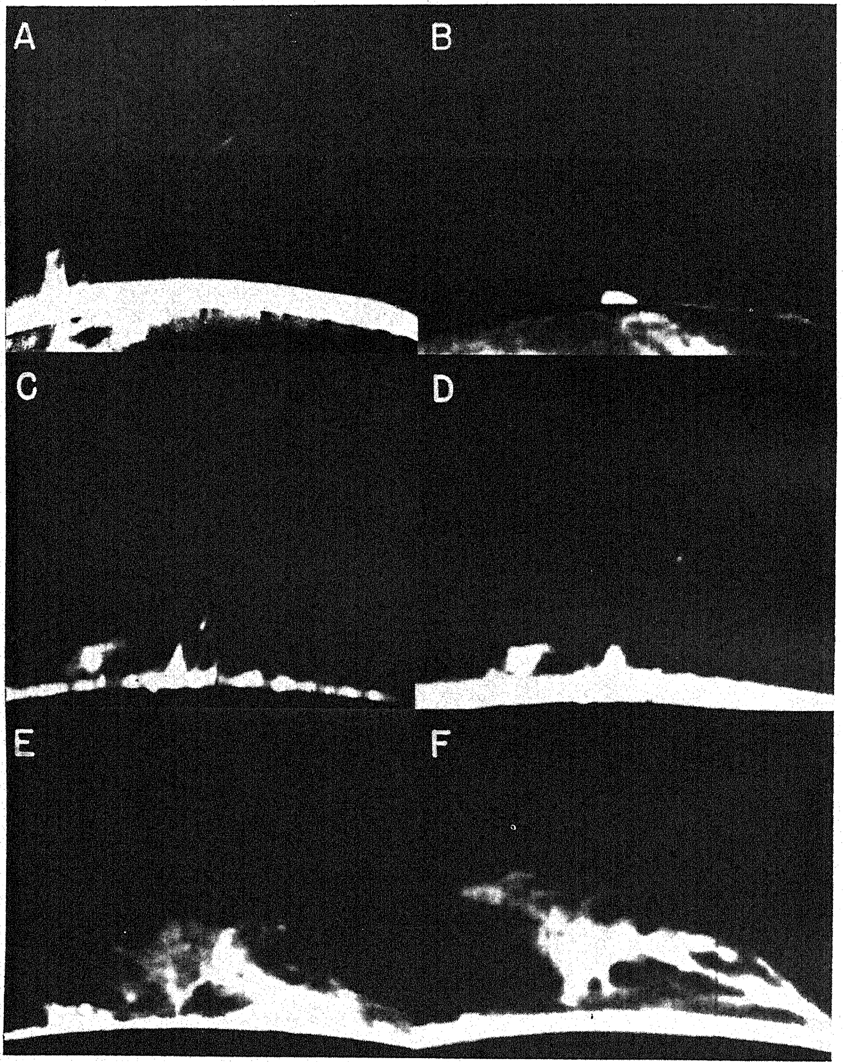
These records of solar prominences in motion have been treated here in a purely descriptive manner, but we should emphasize their value as records of solar phenomena which can, at will, be reenacted for study. Their greatest value, however, lies in the fact that each scene forms an uninterrupted, accurately timed series of observations. This mass of scientific data is contributing to our knowledge of the true characteristics of motions in the outer surface of the sun.

In conclusion, I wish to acknowledge my indebtedness to H. E. Sawyer and Dr. O. C. Mohler, of our staff. They have taken many of the pictures shown in connection with this lecture, and in addition have collaborated in the preparation of this paper. The plates accompanying this paper were prepared by Sawyer and J. T. Brodie, of our staff. I most especially wish to thank Dr. Abbot, Secretary of the Smithsonian Institution, for the honor and privilege of giving the James Arthur lecture here in Washington this month of January 1940.



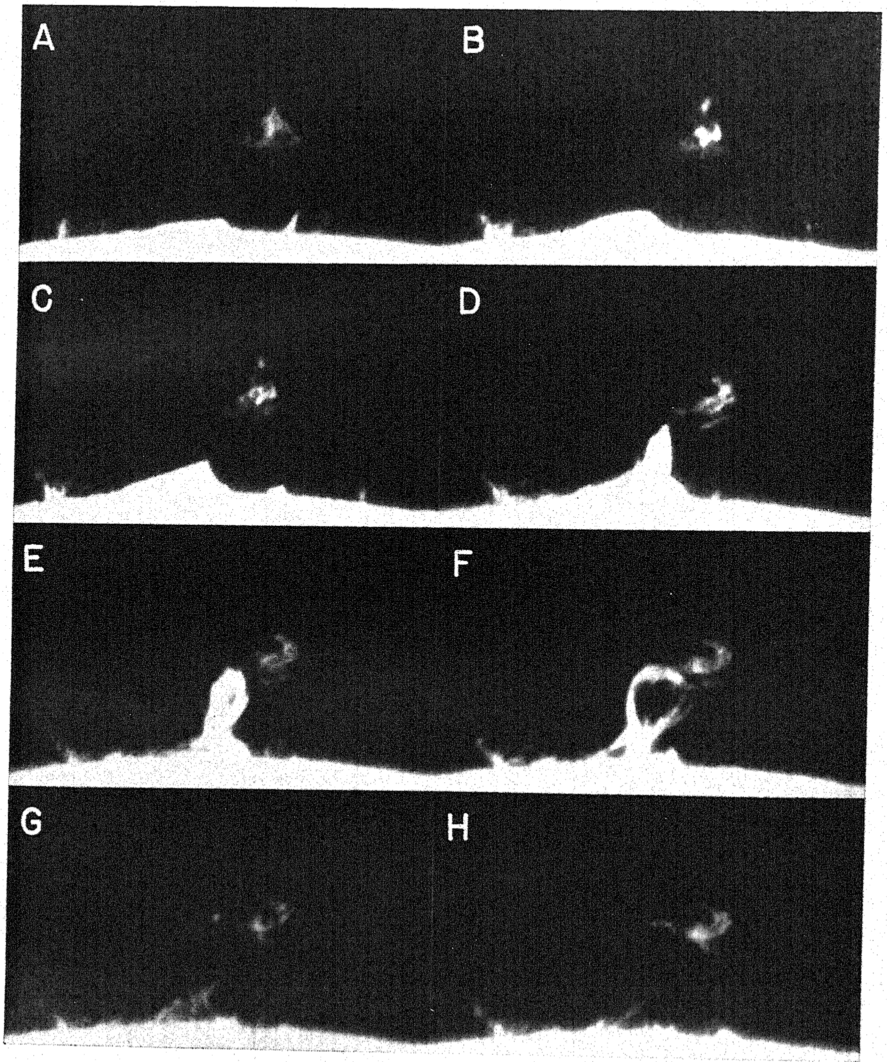
PHOTOGRAPHS OF THE SOLAR DISK.

A, *B*, and *C*, disk of August 18, 1939. *A*, direct; *B*, Hα spectroheliogram; *C*, Ca+ spectroheliogram.
D and *E*, sunspot group of September 1, 1939. *D*, direct; *E*, Hα spectroheliogram.
F and *G*, Hα spectroheliograms of a sunspot group approaching the limb of the sun. *F*, September 14, 1939 *G*, September 16, 1939.



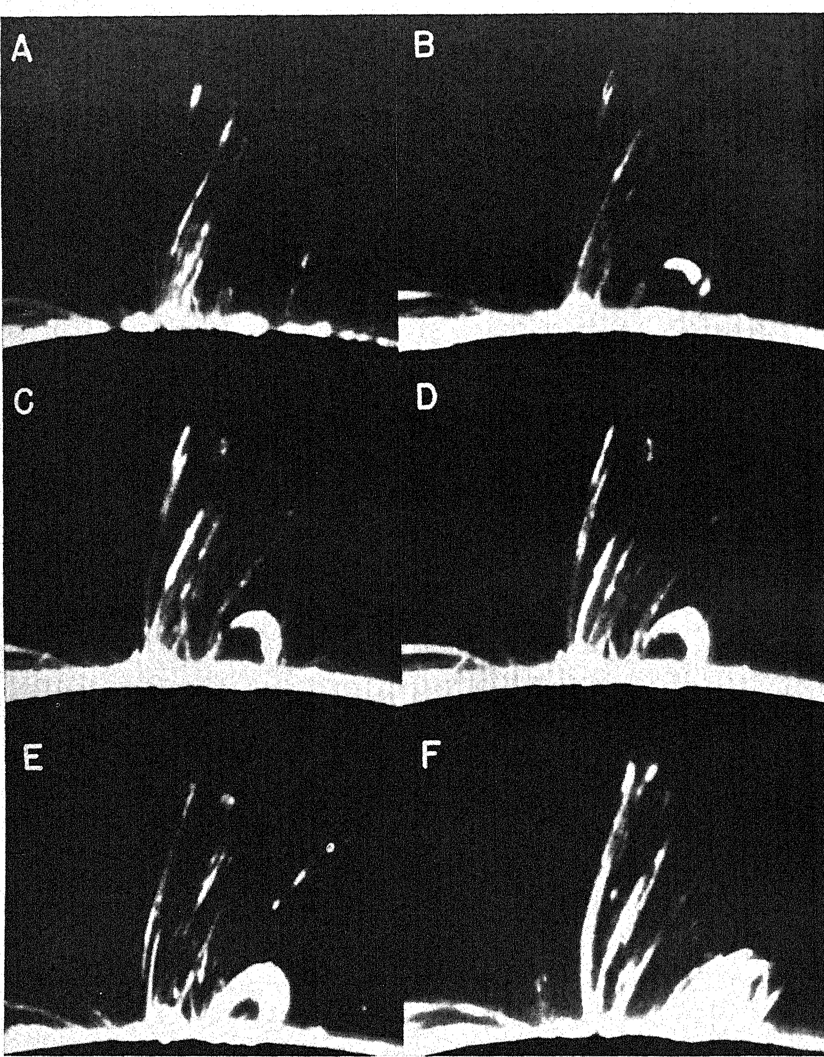
NEW PROMINENCES ADDED TO PETTIT'S CLASSIFICATION.

A, coronal, August 2, 1937, Ca+ spectroheliogram.
B, cap, August 3, 1937, Ca+ spectroheliogram.
C and *D*, surge and ejection of October 25, 1939, Hα spectroheliograms. *C*, 21^{h}18.9^m; *D*, 21^{h}25.32^m G. C. T.
E, quasi-eruptive in "active" stage, July 21, 1939, Ca+ spectroheliogram.
F, quasi-eruptive in "eruptive" stage, July 22, 1939, Ca+ spectroheliogram.



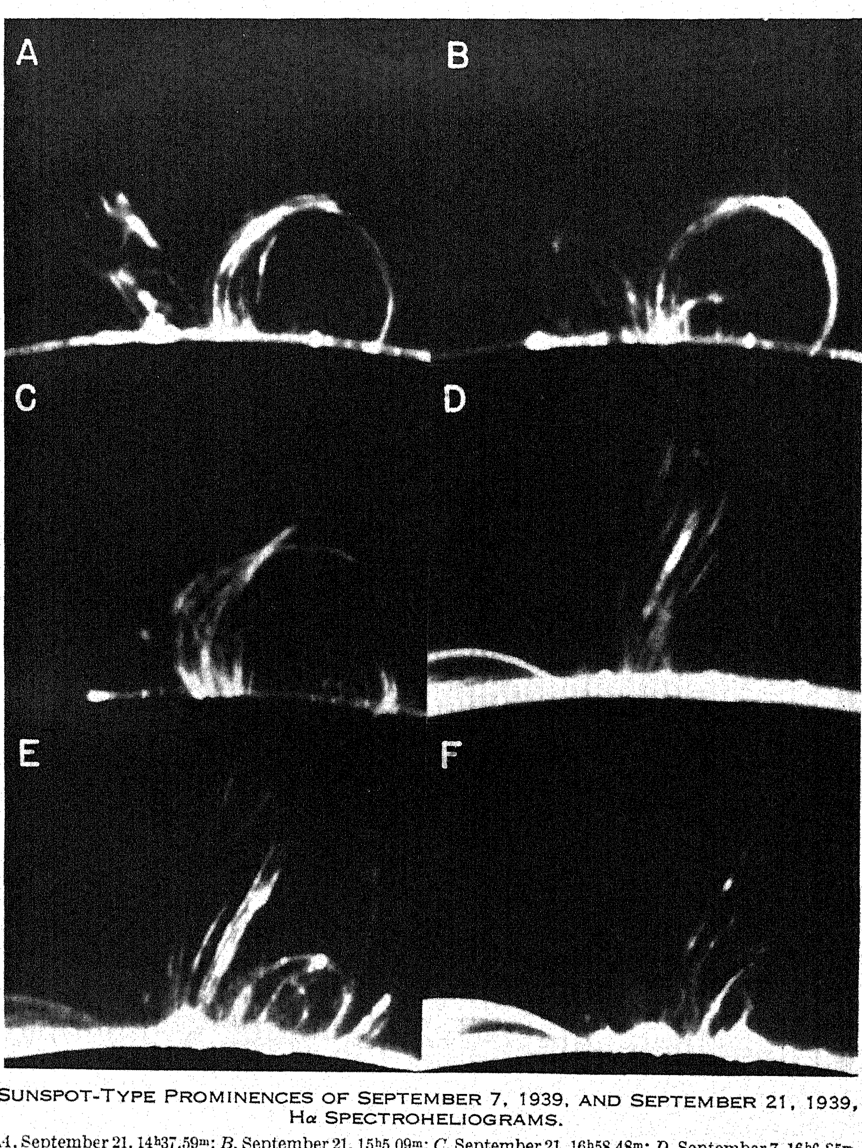
FORMATION OF PROMINENCE, SEPTEMBER 23, 1938, Hα SPECTROHELIOGRAMS.

A, $18^h3.03^m$; *B*, $19^h12.50^m$; *C*, $19^h42.32^m$; *D*, $19^h47.77^m$; *E*, $19^h53.99^m$; *F*, $20^h0.62^m$; *G*, $20^h7.32^m$; *H*, $20^h10.69^m$, G. C. T.



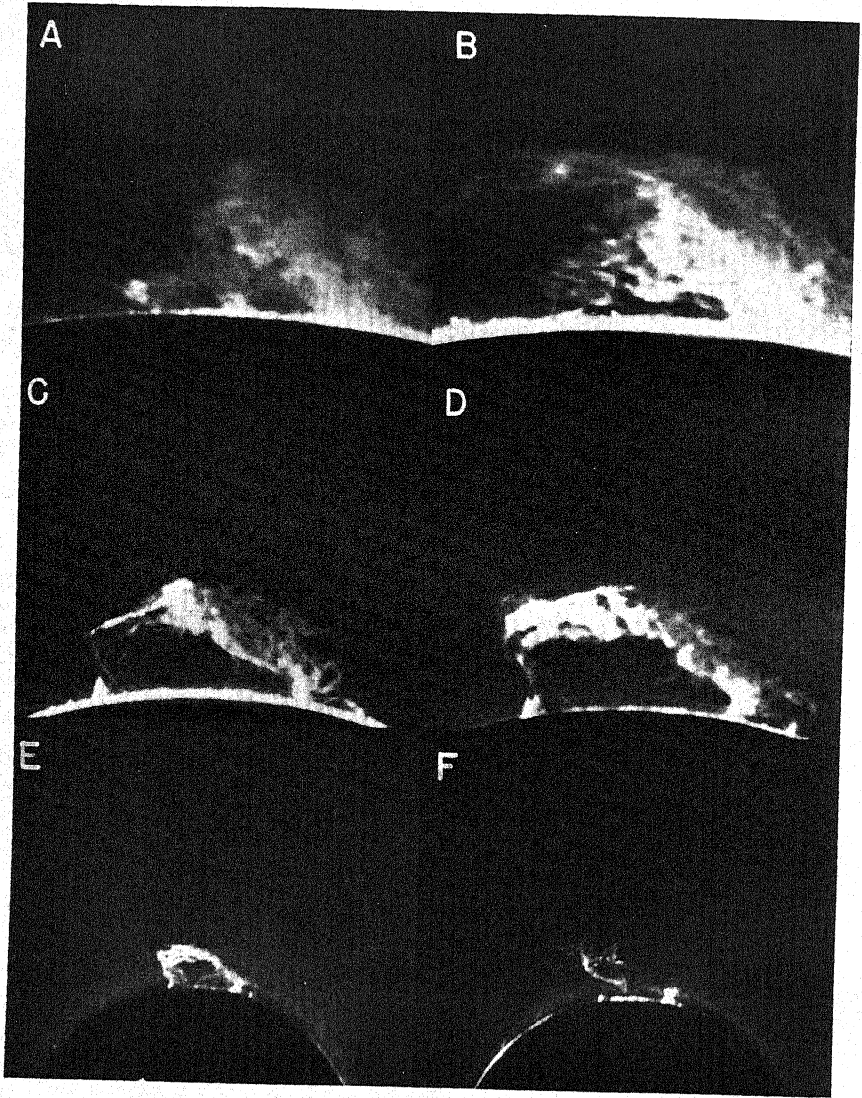
FORMATION OF PROMINENCE LOOP, SEPTEMBER 7, 1939, Hα SPECTROHELIOGRAMS.

A, $16^h20.16^m$; *B*, $16^h23.28^m$; *C* $16^h30.66^m$; *D*, $16^h32.87^m$; *E*, $16^h38.43^m$; *F*, $17^h45.52^m$, G. C. T.



SUNSPOT-TYPE PROMINENCES OF SEPTEMBER 7, 1939, AND SEPTEMBER 21, 1939, Hα SPECTROHELIOGRAMS.

A, September 21, $14^h37.59^m$; *B*, September 21, $15^h5.09^m$; *C*, September 21, $16^h58.48^m$; *D*, September 7, $16^h6.25^m$ *E*, September 7, $18^h40.98^m$; *F*, September 7. $20^h36.81^m$, G. C. T.



QUASI-ERUPTIVE PROMINENCE OF AUGUST 24 AND 25, 1939, CA+ SPECTROHELIOGRAMS.

A, August 24, 15h31.38m; *B*, August 24, 20h37.40m; *C*, August 25, 13h41.46m; *D*, August 25, 17h18.66m; *E*, August 25, 18h49.42m *F*, August 25, 21h7.02m, G. C. T.

THE SATELLITES OF JUPITER [1]

By Seth B. Nicholson

Mount Wilson Observatory, Carnegie Institution of Washington

[With 1 plate]

The four large moons of Jupiter were, as you all know, discovered by Galileo in 1610 with a telescope which he himself had made. This telescope, with an aperture of about 2 inches,[2] magnified some 30 times and was probably the largest and most powerful telescope in existence at that time. The story of how this famous discovery was made is best told in Galileo's own words which are quoted from his account in The Sidereal Messenger as translated by E. S. Carlos.[3]

Discovery of Jupiter's Satellites.—I have now finished my brief account of the observations which I have thus far made with regard to the Moon, the Fixed Stars, and the Galaxy. There remains the matter, which seems to me to deserve to be considered the most important in this work, namely, that I should disclose and publish to the world the occasion of discovering and observing four Planets, never seen from the very beginning of the world up to our own times, their positions, and the observations made during the last two months about their movements and their changes of magnitude; and I summon all astronomers to apply themselves to examine and determine their periodic times, which it has not been permitted me to achieve up to this day, owing to the restriction of my time. I give them warning, however, again, so that they may not approach such an inquiry to no purpose, that they will want a very accurate telescope, and such as I have described in the beginning of this account.

On the 7th day of January in the present year, 1610, in the first hour of the following night, when I was viewing the constellations of the heavens through a telescope, the planet Jupiter presented itself to my view, and as I had prepared for myself a very excellent instrument, I noticed a circumstance which I had never been able to notice before, owing to want of power in my other telescope, namely, that three little stars, small but very bright, were near the planet; and although I believed them to belong to the number of the fixed stars, yet they made me somewhat wonder, because they seemed to be arranged exactly in a

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[1] Public lecture delivered under the auspices of the Astronomical Society of the Pacific in San Francisco on the evening of Monday, January 9, 1939. Reprinted by permission, with slight revision, from Publications of the Astronomical Society of the Pacific, vol. 51, No. 300, April 1939.

[2] It was Galileo's custom to make a much larger lens than the aperture to be used and then to cover with a diaphragm the outer portion of the lens where the figure was poor. The actual aperture used in the discovery of Jupiter's satellites was probably between 1 and 1½ inches.

[3] Shapley and Howarth, A source book in astronomy, p. 49, 1929.

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straight line, parallel to the ecliptic, and to be brighter than the rest of the stars, equal to them in magnitude. The position of them with reference to one another and to Jupiter was as follows:

E * * ○ * W

On the east side there were two stars, and a single one towards the west. The star which was furthest towards the east, and the western star, appeared rather larger than the third.

I scarcely troubled at all about the distance between them and Jupiter, for, as I have already said, at first I believed them to be fixed stars; but when on January 8th, led by some fatality, I turned again to look at the same part of the heavens, I found a very different state of things, for there were three little stars all west of Jupiter, and nearer together than on the previous night, and they were separated from one another by equal intervals, as the accompanying figure shows.

E ○ * * * W

At this point, although I had not turned my thoughts at all upon the approximation of the stars to one another, yet my surprise began to be excited, how Jupiter could one day be found to the east of all the aforesaid fixed stars when the day before it had been west of two of them; and forthwith I became afraid lest the planet might have moved differently from the calculation of astronomers, and so had passed those stars by its own proper motion. I, therefore, waited for the next night with the most intense longing, but I was disappointed of my hope, for the sky was covered with clouds in every direction.

But on January 10th the stars appeared in the following position with regard to Jupiter, the third, as I thought, being hidden by the planet. They were situated just as before, exactly in the same straight line with Jupiter, and along the Zodiac . . . .

E * * ○ W

When I had seen these phenomena, as I knew that corresponding changes of position could not by any means belong to Jupiter, and as, moreover, I

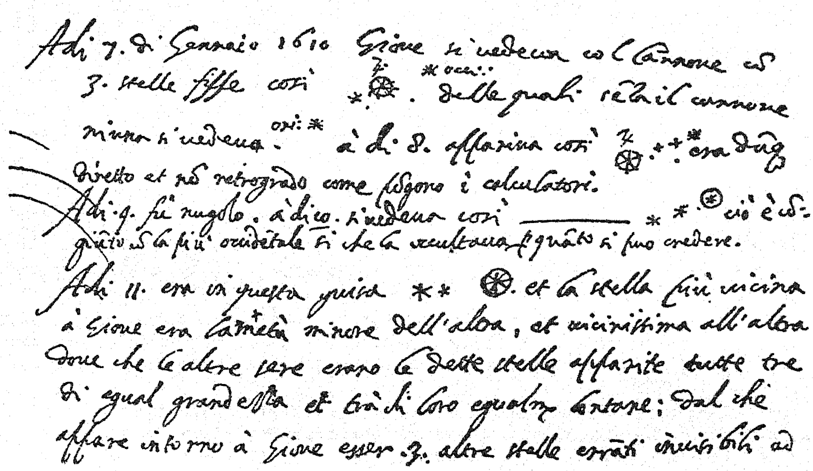

Adi 7. di Gennaio 1610 Giove si vedeva col Cannone con 3. stelle fisse così delle quali senza il cannone niuna si vedeva. à di 8. appariva così era dunque diretto et non retrogrado come pongono i calculatori.
Adi 9. fu nugolo. à di 10. si vedeva così cioè congiunto con la più occidentale sì che la ricopriva per quanto si può credere.
Adi 11. era in questa guisa ** . et la stella più vicina à Giove era la metà minore dell'altra, et vicinissima all'altra dove che le altre sere erano le dette stelle apparite tutte tre di equal grandezza et trà di loro equalmente lontane; dal che appare intorno à Giove esser 3. altre stelle erranti invisibili ad

FIGURE 1.—Part of a page from Galileo's notebook recording the discovery of satellites revolving around Jupiter.

perceived that the stars which I saw had always been the same, for there were no others either in front or behind, within a great distance, along the Zodiac—at length, changing from doubt into surprise, I discovered that the interchange of position which I saw belonged not to Jupiter, but to the stars to which my attention had been drawn, and I thought therefore that they ought to be observed henceforward with more attention and precision.

Accordingly, on January 11th I saw an arrangement of the following kind:

E * * O W

namely, only two stars to the east of Jupiter, the nearer of which was distant from Jupiter three times as far as from the star further to the east; and the star furthest to the east was nearly twice as large as the other one; whereas on the previous night they had appeared nearly of equal magnitude. I, therefore, concluded, and decided unhesitatingly, that there are three stars in the heavens moving about Jupiter, as Venus and Mercury round the Sun; which at length was established as clear as daylight by numerous other subsequent observations. These observations also established that there are not only three, but four, erratic sidereal bodies performing their revolutions round Jupiter. . . . .

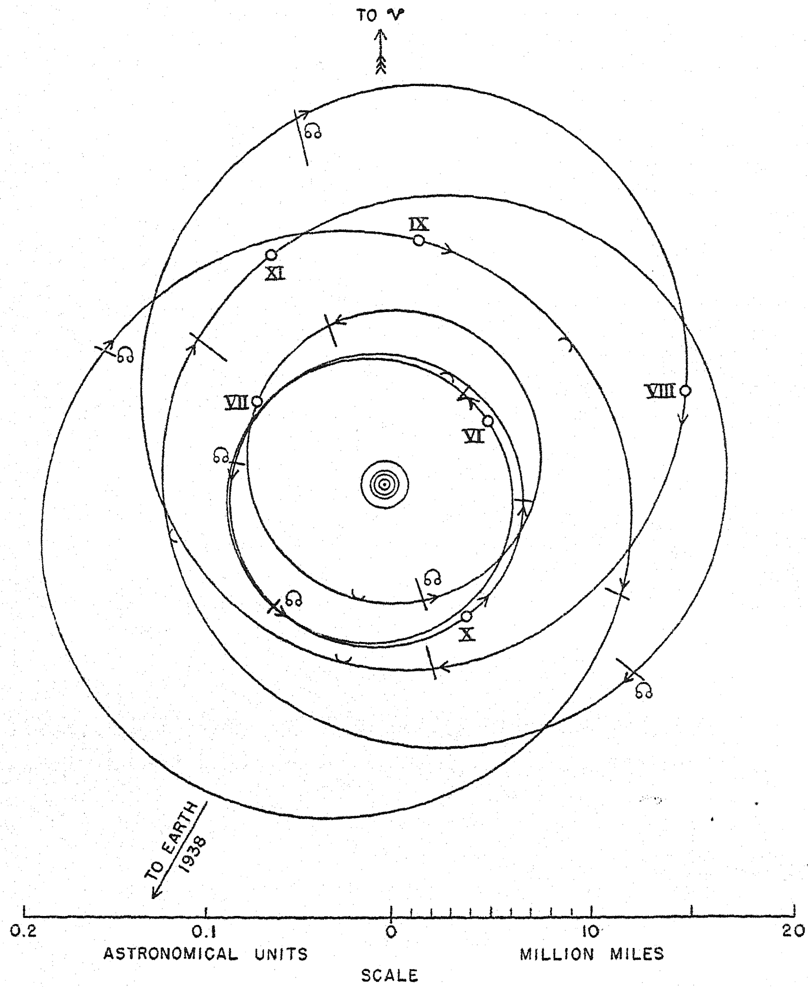
Besides, we have a notable and splendid argument to remove the scruples of those who can tolerate the revolution of the planets round the Sun in the Copernican system, yet are so disturbed by the motion of one Moon about the Earth, while both accomplish an orbit of a year's length about the Sun, that they consider that this theory of the universe must be upset as impossible: for now we have not one planet only revolving about another, while both traverse a vast orbit about the Sun, but our sense of sight presents to us four satellites circling about Jupiter, like the Moon about the Earth, while the whole system travels over a mighty orbit about the Sun in the space of twelve years.

In addition to demonstrating so clearly the nature of the solar system, Jupiter's satellites were responsible for the discovery of another very important fact of nature, namely, that time is required for light to travel from one place to another. In 1675, the Danish astronomer Roemer noticed that when Jupiter was far from the earth the eclipses of its satellites occurred relatively later than when it was near the earth. This delay could be explained if it took time for light to come from Jupiter to the earth, 35 minutes at mean opposition. Since then the speed of light has been measured many times by more exact methods but the result is essentially the same as that obtained from Jupiter's satellites.

After Galileo's time no more satellites of Jupiter were discovered until September 9, 1892, when Professor Barnard, who had been searching with the 36-inch telescope at the Lick Observatory one night each week for 2 months, detected a faint satellite very close to the planet's surface.[4] This fifth moon of Jupiter has the distinction of being the last satellite in the solar system to be discovered visually; since then all such discoveries have been made by photography.

[4] Astrophys. Journ., vol. 12, p. 81, 1892.

In December 1904 a photographic search for faint satellites of Jupiter was begun by Perrine with the Crossley reflector at the Lick Observatory, and on the very first photographs of that search a new



ORBITS OF JUPITER'S SATELLITES

Figure 2.—Orbits of Jupiter's satellites. Each orbit is shown as in its own plane. The line of nodes on the ecliptic is indicated for each orbit; the arrows which show the direction of motion are on the part of the orbit north of the ecliptic. The position of perijove is marked by the arc of a small circle, concave toward Jupiter. The positions of the satellites are those at the opposition of 1938.

satellite was discovered, and a month later, in January 1905, still another.[5] Both were much farther from the planet than the other five. Satellite V revolves around Jupiter in 11 hours and 53 minutes,

[5] Publ. Astron. Soc. Pacific, vol. 17, p. 22, 1905; ibid., p. 63.

the large satellites, I, II, III, and IV, discovered by Galileo, in periods ranging from 1 day and 18 hours to 16 days and 16 hours, but VI and VII, discovered by Perrine, are so far away from Jupiter that 260 days are required for them to encircle the planet.

In 1908 Melotte at Greenwich, England, while photographing the sixth and seventh satellites, discovered an eighth.[6] It was still farther from Jupiter and required 750 days to complete its journey around the planet. Still more peculiar was the fact that it moved in a retrograde direction, opposite to that of all the other satellites of Jupiter. In 1914, while a graduate student at the Lick Observatory, I was assigned the task of photographing the distant satellites of Jupiter to see how closely they were following their calculated paths. A ninth satellite was found[7] on photographs of the eighth, just as some years before, the eighth had been found by Melotte near the sixth and seventh. The period of the ninth satellite is almost the same as that of the eighth and it also revolves in a retrograde direction.

Satellites VIII and IX are so far from Jupiter that their motions are greatly disturbed by the gravitational attraction of the Sun, and their paths around Jupiter do not even approximate closed curves. The computation of their positions is therefore a difficult task and it has been necessary to observe them frequently to prevent their being lost. In the past 20 years, whenever Jupiter has been near the earth, they have, therefore, been photographed many times, and such photographs have always been examined for additional satellites, but none has been found.

Since no systematic search for undiscovered satellites had ever been made with a telescope larger than 36 inches in diameter, it seemed worth while to make such a search with the 100-inch reflector, and accordingly that project was made a part of the observing program at the Mount Wilson Observatory in the summer of 1938. The plan was to photograph the region around Jupiter at the Newtonian focus of the 100-inch reflector on 8- by 10-inch plates with exposures of 1 hour each. The survey covered about 10 square degrees extending 3 degrees east and west and a degree and a quarter to the north and south of Jupiter. The photographs, which partially overlapped, covered 54′ by 68′ each and reached magnitude 20 over most of that area. The survey was completed from July 27 to August 1 except for two fields, which were photographed on August 25. Six additional fields, three on each side of Jupiter had been photographed on July 5 and 6 to record any satellites that would be hidden in the glare near Jupiter at the time of the principal survey 3 weeks later.

[6] Mon. Not., vol. 68, p. 373, 1908.
[7] Publ. Astron. Soc. Pacific, vol. 26, p. 196, 1914.

Very faint satellites would not show on photographs made even with a large telescope guided in the ordinary way because, during the necessarily long exposures, they would move, and therefore fail to register. By moving the telescope to follow Jupiter during the exposure, images of the very faint satellites which move very little relative to Jupiter in 1 hour, can be made to fall nearly at the same spot on the photographic plate during the whole exposure, thus leaving a visible image. On such a plate the brighter stars make elongated images easily distinguished from the round image left by a satellite.

One or more of the thousands of asteroids which revolve around the Sun between the orbits of Mars and Jupiter registered on almost every photograph taken in the search. The motions of these tiny planets are, however, generally faster than that of Jupiter, and their images are somewhat elongated, although not so much as the images of stars. About 40 moving objects were found in the course of the search. Among these were the known satellites VI, VII, VIII, and IX, and 5 other objects which were moving along with Jupiter.

Satellites VI and VII were identified by their positions given in the American Ephemeris and Nautical Almanac, and VIII by an ephemeris computed by Hertz of Yale. No ephemeris of J IX was computed until after the survey was finished so that the rediscovery of that satellite served as a check on the completeness of the survey.

The five unidentified objects were followed until their motions identified two of them as new satellites of Jupiter [8] and the other three as asteroids which happened to be nearly in line with Jupiter for a few days.

The new moons are very faint and anyone who wishes to observe them should remember the advice Galileo gave to those who might try to see the satellites he had just discovered. "I give them warning, however, again so that they may not approach such an inquiry to no purpose, that they will need a very accurate telescope." The new satellites can be photographed with a telescope smaller than the 100-inch reflector if a sufficiently long exposure is given but it would be difficult to photograph them with an aperture much smaller than 36 inches. No effort has been made to see them that I know of, and at the present time there is only one telescope with which they could be seen, the 100-inch telescope of the Mount Wilson Observatory. All the previously discovered satellites of Jupiter have been seen with that telescope, even IX, which is just as faint as XI and almost as faint as X.[9] An idea of the extreme faintness of

[8] Publ. Astron. Soc. Pacific, vol. 50, p. 292, 1938.
[9] Publ. Astron. Soc. Pacific, vol. 50, p. 350, 1938.

these objects may be obtained by comparing their brightness with that of a candle. If the light of a candle were not absorbed by the earth's atmosphere it would have to be viewed from a distance of 3,000 miles in order to appear as faint as they are. They are so small and so far from the planet that an observer on Jupiter itself would require a 6-inch telescope to see them. Photographs of an hour's exposure with the 100-inch telescope are capable of showing much fainter objects than those that were found, and the fact that fainter satellites were not found indicates that, if Jupiter has more undiscovered satellites, they are probably much fainter than those now known.

The size of the new satellites, although not directly measurable, can be inferred from the measured brightness and an assumed value of the surface brightness.[10] Satellite X is fainter than XI and therefore probably smaller. Unless their surfaces are extremely dark, their diameters must be less than 15 and 19 miles, respectively. The diameters of the other faint satellites of Jupiter, likewise inferred from their brightness, are: V and VI, 90 miles; VII and VIII, 25 miles; IX, 19 miles. The satellites discovered by Galileo are huge in comparison. The smallest is 2,000 miles in diameter, almost the same size as our Moon; the largest, 3,000 miles in diameter, is as big as the planet Mercury.

Satellite X, like VI and VII, revolves around Jupiter in a period of about 260 days, and in the same direction in which they move. The orbit of satellite XI is still not accurately known but the preliminary calculations show that it revolves in the same direction as VIII and IX, in a period of about 700 days.

The five inner satellites form a family group at an average distance of a little less than 1 million miles from the planet, all revolving nearly in the plane of Jupiter's equator. Satellites VI, VII, and X form another family at a distance of 7 million miles, while VIII, IX, and XI form still a third, 15 million miles from the planet. The characteristics of each group are so closely accordant that they cannot be the result of chance. Whether the small outer satellites have been captured by Jupiter is a debated question, but the fact that they exist in families seems to point toward a common origin for each group unless it can be shown that satellites of Jupiter have much more stable orbits at distances of 7 and 15 million miles than at other distances.

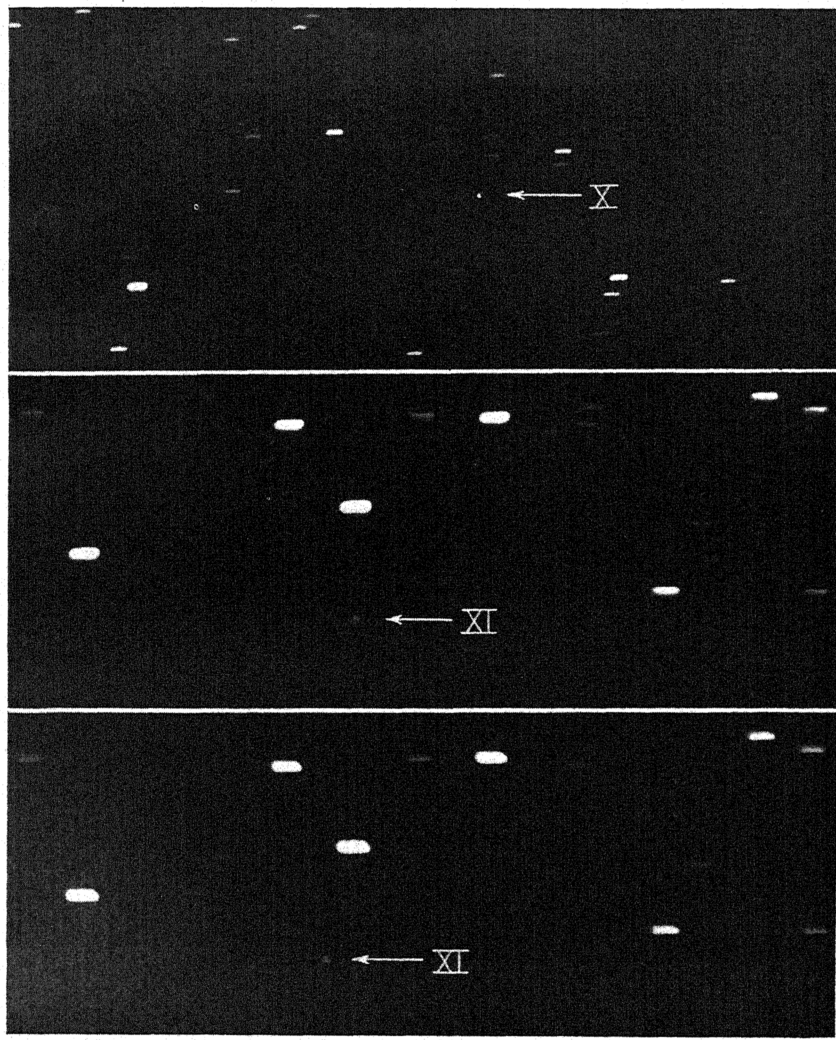
Many have asked what the new satellites are to be named. They will be known only by the numbers X and XI, written in roman

[10] The diameter of a satellite of Jupiter may be computed by the formula

$$\log d = 4.46 - 0.2\ m - \log \sqrt{p}$$

where d is the diameter in miles, m is the photographic magnitude at mean opposition, and p is a factor, closely related to the albedo, which for the darker satellites and asteroids has a value of about 0.1.

numerals, and usually prefixed by the letter J to identify them with Jupiter. The four satellites discovered by Galileo were once named but they are more commonly referred to as satellites I, II, III, and IV than by their names, Io, Europa, Ganymede, and Callisto. The satellites of Mars, Saturn, Uranus, and Neptune all have names, although the name of Neptune's satellite, Triton, is not generally used. When Barnard discovered the fifth satellite of Jupiter many names were proposed for it but none was adopted. Barnard thought that, since the names of the four bright satellites were so little used, the new satellite should simply be called the Fifth Satellite. His suggestion was followed and a similar custom has prevailed for all those discovered since. This custom is very convenient and makes it possible to foretell the name of the next satellite, should another be discovered. It will be J XII.



SATELLITES X AND XI OF JUPITER.

J X. 1938, August 25. Exposure 31 min. Length of star trails 10″. Image centered on plate.
J XI. Discovery plates, 1938, July 30. Exposure 60 min. Length of star trails 15″. The image of the satellite was 26′ from the center of the plate on the upper reproduction and 29′ on the lower.

CULTURAL VALUES OF PHYSICS[1]

By David Dietz

Science Editor of the Scripps-Howard Newspapers

I

There was a time when the classics formed the cultural bond that united educated men throughout the world. Every high-school boy read his Caesar, Cicero, and Virgil in Latin, his Xenophon and Homer in Greek. He continued in college with Horace and the other Latin poets and made the acquaintance of the Greek dramatists and philosophers. Thus all educated men were bound together by a common educational experience and their thinking was rooted in a common source of inspiration, the classical learning of ancient Rome and Greece.

With the rise of the twentieth century, the classics lost their hold. I do not suppose that there is a college in America which lists a knowledge of Greek among its entrance requirements. Many colleges, including, of course, the scientific schools, do not require Latin.

The dethronement of the classics is so nearly complete today that it is doubtful if the young student, stepping upon a college campus for the first time, realizes the change which has taken place in the structure of education. I carry a sharp picture of the changing process since it was my interesting fortune to live through it.

The decline of the classics has, unquestionably, been a byproduct of the rise of science. Many educators, however, have lamented the fact that there is no longer a common cultural tie among learned men. For with the rise of science has come the rise of specialties and with the rise of specialties has come a division of tongues. Each specialist speaks a language of his own and this fact has sometimes been a handicap to understanding and a stumbling block to progress.

It is inevitable that each specialist must pursue his own line of attack farther and farther into the frontier of the unknown. It is, therefore, equally inevitable that these pioneers must draw away

[1] Address given at the annual meeting of the Pennsylvania Conference of College Physics Teachers, Pennsylvania State College, October 14, 1938. Reprinted by permission from Journal of Applied Physics, vol. 10, February 1939.

farther and farther from each other. But this makes it all the more essential that there be some common bond of understanding both for them and for all educated men in general.

Since this is preeminently an age of science, an age chiefly distinguished for its advances in scientific understanding and engineering achievement, it is obvious that such a common basis must be found in the realm of science. I am firmly convinced that there is only one subject that can furnish this necessary foundation for modern education. It is the subject of physics. I wish to urge, therefore, that educators everywhere give thought to ways of shaping educational policies to bring about this united emphasis upon the teaching of physics.

II

Physics derives its first great cultural value from the fact that the present age cannot be understood without an understanding of physics. Physics is the foundation stone of the age in which we live. It was ushered in by discoveries in the realm of physics.

It was the announcement of the X-ray by Roentgen in 1895, followed in quick succession by Becquerel's disclosure of radioactivity, the isolation of radium by the Curies, and the researches into the nature of the atom and the electronic theory of matter by Thomson, Lorentz, Rutherford, Soddy, and others which ushered in the magnificent edifice of twentieth-century science. These discoveries not only set the pace but furnished the foundation for the century's growth. In 1900 the electron was a theory. In the next decade, Dr. Millikan was to perform his famous experiments to measure the electric charge upon the electron, experiments destined to win the Nobel prize in physics. Today, the world has put the electron to work. In the vacuum tubes of our radio sets, in the photoelectric cell, in other electronic tubes and in the X-ray tube, we are making daily use of the electron (1).[2]

It will be seen, therefore, that only through a knowledge of physics can the student gain the historical perspective needed for an understanding of the temper and the tempo of the age in which we live.

But we need an understanding of physics just as much for the comprehension of the individual details which make up the picture of our modern age. Without it, the radio set is a complete riddle, the gasoline engine becomes a baffling puzzle, the electric light, a mystery without explanation. We can only understand these things and the countless other mechanical and electrical marvels around us

[2] Numbers in parentheses refer to bibliography at end of article.

with the aid of the principles of physics. And this fact brings me to another great cultural value of physics.

Physics derives its second great cultural value from the fact that it is the foundation of all the sciences. This has not always been realized for many reasons.

In the first place, a trick of language alienated physics from its offspring and obscured the connection. Applied physics became known as engineering and the applications of physics were disseminated under the names of mechanical engineering, civil engineering metallurgy, electrical engineering, and so on. But let us not forget that it was the physicist who launched each of these specialties. It was Galileo who laid down the fundamental laws of the machine. Newton's mathematical expression of Galileo's dictum, force equals mass times acceleration, is the foundation of every machine in the world. Similarly, electrical engineering grew from the experiments of Oersted, Ampère, Faraday, and Ohm. The first principles of every engineering science are the laws of physics and no real understanding of engineering advances is possible without a knowledge of physics.

The fundamental position of physics as the foundation stone of all science was missed, in the second place, because in certain branches of science this relationship was not at first clear. It took time to bring the development of atomic theory to the point where it was plain that chemical phenomena represented the operation of physical laws. Today we see the relationship of chemistry to physics clearly expressed by the use of the term "physical chemistry" which, perhaps, might just as well be written "chemical physics." The chemist invokes the laws of physics to explain the behavior of atoms and often we find both chemists and physicists working upon identical problems.

Biology, long regarded as a thing apart, has been brought into the fold of the physical sciences. This recognition of relationship was first celebrated with the creation of "biochemistry," a field of research which has been unusually fruitful. More recently this has been extended into "biophysics." Not long ago I was talking to the director of an important medical laboratory in the Middle West. "You will be surprised to know the latest addition to my staff," he said. "It is a full-time physicist."

This new demand for well-trained mathematical and experimental physicists in many laboratories outside the realm of physics, is one of the most interesting and important trends of our times. Not only are chemical, biological, and medical laboratories seeking the aid and services of physicists, but many industrial laboratories are discovering that chemists and engineers are not sufficient to deal with the intricate problems met today in mining, metallurgy, electrical

design and construction, and many other fields. This trend was discussed at some length at the Conference on Industrial Physics arranged by the physics department of the University of Pittsburgh on November 15, 1935 (2). I had the honor of appearing on that program (3) and I remember well the discussions there, particularly the paper by Dr. A. W. Hull of the General Electric Co. entitled "Putting Physics to Work" (4).

The physicist is doing his share to usher in the new world of taller buildings, longer bridges, swifter trains, safer aircraft, and finer homes, a new world of greater beauty, deeper comfort, and smoother efficiency. He is helping to build this new world out of stronger steels, tougher alloys, better aluminum products, more useful plastics, harder abrasives, more powerful machine tools, and more ingenious automatic controls.

III

A third great cultural value of physics is derived from the importance of physics for the future. I like to talk about the future for I believe that we should face the future with courage and confidence. I believe that the world will move within the next century into a period far more remarkable than the present, and I believe that the leadership for this great progress will come from America.

I have spoken of the taller buildings, the longer bridges, and the faster trains and airplanes that are now evolving. But no bigger mistake could be made than to think of the future as nothing more than an exaggerated picture of the present.

This is the mistake, as the British satirist and caricaturist, Max Beerbohm, has pointed out, that every century has made. The sixteenth century thought that the seventeenth century would be only a magnified picture of itself. The seventeenth thought the same of the eighteenth, and the eighteenth thought likewise of the nineteenth. Yet each century had a personality and a development all its own.

How smug the nineteenth century was in this regard can best be described by borrowing a story from Dr. Millikan. He tells how, as a student in Europe, he attended the annual session of the British Association for the Advancement of Science in 1893. An eminent British physicist rose to address that august assembly and spent his time giving thanks that he had lived at the close of the nineteenth century. For, he said, the nineteenth century had seen the completion of the great edifice of physics. All the laws of nature had been discovered and cataloged. Nothing remained for the physicists of the future but to repeat the experiments of the past. Perhaps some twentieth-century physicist might carry to four decimal places a determination which the nineteenth-century physicist had left at three.

And how quickly that smug view of nature was overturned! Just 2 years later, in 1895, Roentgen showed the German Physical Society

the world's first X-ray pictures. Those pictures—so commonplace today, so startling then, the picture of coins and keys showing through the leather walls of a purse, of bones showing through the skin and flesh of a human hand—those pictures were proof that far from completing the cataloging of nature's laws, the nineteenth-century physicist had only made a beginning.

In thinking of the twenty-first century, I would ask you not to look at those things which represent the most complete accomplishments of our present day but to look at those things which we are just now beginning to comprehend. I would ask you to visit the laboratories and study the researches under way rather than to visit the factory or the market place to study the finished achievements.

Sometimes these laboratory experiments look confused and useless, but let us not fool ourselves. I am reminded of the story of the visit which the Prime Minister of England paid to Faraday's laboratory at the Royal Institution in London. Faraday was then engaged in those experiments upon the laws of electricity, experiments in physics, if you please, from which have come every electric generator, transformer, and motor in the world.

"What's the use of all this?" the Prime Minister asked Faraday.

"Don't worry, milord," Faraday is said to have replied, "you'll tax it yet."

When we recall all the taxes paid today by the electrical industry, and all the taxes we help pay when we pay our electric-light bills, we are inclined to agree with Faraday.

And I am reminded of another story, this one about our own great statesman, patriot, and physicist, Benjamin Franklin. That worthy did many things his neighbors did not altogether understand, like flying kites, for example. One day, a neighbor woman asked Ben the very same question that the Prime Minister had asked Faraday. "Ben," she said, "what's the use of all this?" And Franklin being a good Yankee, replied in Yankee fashion with another question. "What's the use of a baby?" he asked.

We all know the answer to that question. A baby can grow up to be a very useful man or woman, and when we see the veritable giant into which the baby electricity has grown, we realize the wisdom of Franklin.

Now when you attempt to picture the future I want you to give thought to some of the babies of the physical laboratory. They will grow up to make the twenty-first century a personality in its own right, different from the century we know.

I think first of the "babies" in the field of the production of power. The age in which we live rests upon a foundation of physical power. Imagine, for a moment, what would happen to our great cities if electric power and the power of the gasoline engine were

suddenly removed. Every electric light would go out. Every electric motor would stop. Every automobile would become useless.

Physical power is the basis of economic and national power. Professor Leith, of the University of Wisconsin, has pointed out that it is often said that the World War transferred world power from Great Britain to America. But he believes that the World War only made evident what had already happened. In the nineteenth century, Great Britain produced half of the world's physical power. Today, the output of energy in the United States from coal, oil, natural gas, and water power amounts to half of the world's total. It is this fact, rather than the last war, Professor Leith believes, that explains the dominant position of America in the world of today (5).

Any new source of energy, therefore, will be of supreme importance to the future and a cheap and abundant source of energy will change the shape of the future in ways which we can only attempt to guess. As is well known to you, attempts are being made to find such sources of power.

It is being sought, first of all, in attempts to put the sun to work. It would not be fair to say that the sun's energy goes to waste, since its light and heat makes life upon this earth possible. But it is perfectly true that we waste the greater part of the energy which the sun sends us. It has been calculated that the amount of energy falling upon every square yard of earth's surface per second is the equivalent of 1⅓ horsepower.

Physicists have long dreamed of putting this solar energy to work. One of the first suggestions made was to concentrate the sun's heat by means of mirrors upon a steam boiler. Dr. C. G. Abbot, Secretary of the Smithsonian Institution, has been a pioneer in this field, and his solar engine (6), which has been exhibited at meetings of the American Association for the Advancement of Science, at the Great Lakes Exhibition in Cleveland, and elsewhere, is well known to many of you. Dr. Abbot incorporated many ingenious features in his device. A parabolic mirror concentrates sunlight upon the boiler which is actually two concentric glass tubes with a vacuum between them. Thus while there is only a slight barrier to the entrance of the sun's radiant energy, there is a considerable barrier against the loss of heat by atmospheric conduction. Steam is generated in the inner tube upon the flash-boiler principle.

Another method for the utilization of solar energy which seems highly promising to many scientists is the conversion of sunlight into electricity by photoelectric methods.

About a year ago, on a visit to the research laboratories of the Westinghouse Electric & Manufacturing Co. at East Pittsburgh, I was shown four photoelectric cells like those used in light meters

which had been connected to a toy electric motor, the sort you might buy for a small boy at Christmas. When sunlight fell upon the cells, enough electricity was generated to run the motor. The research men referred to the motor laughingly as "a 1 fly-power motor." But, again, it must be remembered that we were looking at a scientific baby.

Perhaps the day will come when our houses will be roofed with photoelectric cells, instead of shingles, and we will make electricity, instead of hay, while the sun shines.

It is of the utmost significance that during the present year both Harvard University and Massachusetts Institute of Technology were given funds totaling about $1,000,000 by Dr. Godfrey L. Cabot to investigate the problem of solar energy. M. I. T. is to concentrate upon the direct utilization of solar energy by such means as I have been describing, while Harvard is to investigate photosynthesis, the method by which plants utilize solar energy.

Another direction in which many scientists are looking for a new source of energy is the interior of the atom. That the conversion of matter into energy would release tremendous stores of power was shown as early as 1905 when Albert Einstein wrote his equations for the inertia of energy. Experiments in artificial radioactivity during the last 5 years have confirmed these equations of Einstein.

As you know, it has been calculated that the atomic energy in a glass of water would be enough to drive an ocean liner from New York to Cherbourg and back again. It is easy to see how different a world this would be if, instead of filling your automobile tank with gasoline every other day, you merely filled it with water once a year.

Second in importance to power in this world of ours, is the possession of raw materials. Here again we are fortunate to be citizens of America since this Nation is the largest owner, producer, and consumer of minerals, leading in the production of iron, copper, lead, zinc, aluminum, phosphates, gypsum, and sulphur (5).

But the world's greatest reservoir of minerals is the ocean. A new world would dawn if we once learned to mine the ocean successfully. This is not as wild an idea as it sounds, for, as many of you know, a successful beginning has already been made.

If you use ethyl gasoline in your automobile, the chances are that it was made with bromine that was mined from the ocean. At Kure Beach, near Wilmington, N. C., is the plant of the Ethyl-Dow Chemical Co. Sea water is pumped through the plant and bromine extracted from it by a relatively simple chemical process.

During the course of a year, the two giant, electrically driven centrifugal pumps lift about a square mile of ocean, 80 feet deep, into the towers of the Ethyl-Dow plant at Kure Beach. Chemists of the

plant calculate that while they got the bromine out of that volume of sea water they missed about $96,379,460 worth of mineral wealth. Included in it was $29,300 worth of silver and $42,000 worth of gold.

While gold and silver appeal to our imaginations, a far greater amount of wealth was in that sea water in the form of sodium chloride, epsom salts, calcium chloride, potassium chloride, aluminum, magnesium, strontium carbonate, iron, copper, and iodine.

From the physical laboratory may come techniques in the future which will extend the ability of man to mine the ocean. And it takes little imagination to perceive how profoundly this will change the trend of civilization.

I have alluded to the new studies at Harvard upon photosynthesis. Perhaps some day, as Dr. Slosson once suggested, we may know as much chemistry as a tree. Perhaps we should say as much physics as a tree. When that day comes, artificial photosynthesis will be possible, and perhaps we will solve the farm problem by abolishing the farm and the cycle of the soil and by manufacturing our food in factories run by sunlight.

We may also expect great changes in the future from the application of physics to biology and medicine. Recently, as some of you know, I undertook to survey the field of medicine in my book, Medical Magic. I devoted the last chapter of the book to a glance at the future and in it I wrote: "Of one thing we can be certain: that every advance in chemistry and physics, every new step in the understanding of the behavior of the molecule, the atom, and the electron, will have its influence upon medical progress. Already the medical laboratories of the world are making use of all the knowledge that physics and chemistry has to offer" (7).

IV

An example of the application of the technique of physics to biology is the development of the so-called brain-wave machine in which vacuum-tube amplifiers are used to amplify the electrical currents generated in the brain. A new concept of brain activity and a new understanding of the nerve cell, its functions, and its behavior, are coming from these studies.

In the study of the potent drugs of life, the hormones, the vitamins, the enzymes, and the other important chemical factors, the constant attempt is to isolate them in pure crystalline form so that they may be studied with all the resources of the modern chemical and physical laboratory.

Biologists have always associated activity with life, and for many decades now they have known that a vast amount of action goes on within the living organism. They have been aware of the beating

of the heart that keeps the blood in circulation, the rhythmic motion of the lungs that supplies oxygen to the blood stream, the complex chemical activities of the digestive apparatus and other organs. More recently they have learned something about the living drug factories, the ductless glands, and about the electrochemical messages that flow along the nerve fibers.

But new experiments, applying the latest discoveries of atomic physics to the problems of physiology, have disclosed a veritable cyclone of activity within the human body such as was never before suspected. The recent discovery of artificial radioactivity has made possible these new findings.

At the Harvard Tercentenary Conference, Prof. August Krogh (8), the distinguished biologist of the University of Copenhagen, reported experiments in which radioactive phosphorus was fed to rats. He reported that within a short time this radioactive phosphorus had left the blood, exchanging places with the ordinary phosphorus of the tissues. This exchange involved the muscles and other organs. Even more astounding, he said, was the fact that this radioactive phosphorus found its ways into the bones and teeth. He believes, therefore, that we must change our views of the structure of living organisms, accepting a constant movement of atoms within it such as was never previously pictured.

It is interesting to speculate what life may be like when our knowledge of the chemistry and physics of the human body has become so great as to give us such control over it as is undreamed of today.

Perhaps the tme is coming when it will be possible to make a hormone survey of the growing child. A few drops of his blood, carefully extracted from a pinprick in a finger, placed in a test tube and sent to the laboratory for analysis, may reveal far more about the child than any present-day method. Perhaps by that day, the physician will also possess sufficient knowledge to act upon what the analysis will show.

Who can say how successful these methods may prove eventually? Perhaps the muscles of the strongest child are the rightful heritage of every child, the keenest brain the birthright of every infant.

The whole world is thrilled when a youthful Yehudi Menuhin strides out upon the concert stage, playing the works of Beethoven and Brahms with the brilliant understanding of a mature genius. The whole world stares in amazement when an 8-year-old boy turns out to be a "marvel" at chess, playing 50 simultaneous matches against masters of the game and winning them all.

Perhaps the genius that makes a Yehudi Menuhin or a chess marvel lurks within every child.

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If you drive an automobile you have no doubt experienced a time when the car developed engine trouble. The motor sputtered and backfired; it ran haltingly and noisily. You took the car to a garage where a trained mechanic rolled up his sleeves and got out an assortment of tools and wrenches. He regulated the carburetor and made other minor adjustments. Soon the engine began to run smoothly and quietly, quickly gaining its full efficiency.

It may be that every human being is like the automobile engine that is not quite correctly adjusted. It may be that tiny adjustments, if we knew how to make them, would open up the potentiality of genius for every child. Perhaps that hope is extravagant, but there seems every reason to believe that the time is coming when far more will be accomplished to insure stronger bodies, healthier nerves, stabler dispositions, and keener minds for every child than at the present time.

V

Physics derives its fourth great cultural value from the fact that it is the foundation stone of all attempts to understand the universe. We have just been considering the basic relationship which physics bears to chemistry and biology. That relationship applies equally to astronomy and cosmogony. I attempted to trace this essential unity of the universe in my first book, The Story of Science (9).

The universe is one. The same fundamental laws that govern the electrons in the atom control the stars in the Milky Way. Modern science has achieved its greatest triumph in tracing the organization of the universe from the tiny electron to the great clouds of galaxies. This has been done with the aid of physics. Perhaps it was in this field that the importance of physics was first most clearly realized. Galileo was an astronomer as well as a physicist and the laws which he and later Newton developed were seen at once to apply to the heavens as well as the earth. Appropriately enough the study of planetary motions was christened "celestial mechanics."

Newton in his law of universal gravitation stated a rule that applies as truly to the double star 500 light-years away as it does to the apple falling from the branch of a tree.

The kinship of physics and astronomy became clearer with the investigations of the nature of light and the invention of the spectroscope, and this kinship was duly celebrated with the christening of this branch of study as "astrophysics."

In his attempts to solve the problem of the evolution of the galaxy, the genesis of the sun's heat, the origin of the solar system, and many other fascinating problems of the heavens, the astronomer turns to the knowledge which the physicist has accumulated about

the behavior of subatomic particles and energy photons. He employs the experimental apparatus of the physics laboratory and the equations of the mathematical physicist.

"Matter and force are the two names of the one Artist who fashions the living as well as the lifeless," wrote the great Huxley. But the modern view puts the greater emphasis upon energy.

"All the life of the universe," says Sir James Jeans, "may be regarded as manifestations of energy masquerading in various forms, and all the changes in the universe as energy running about from one of these forms to the other, but always without altering its total amount" (10).

In our attempts to construct a universe, therefore, we may regard all the various subatomic particles as concentrated energy, "bottled energy" if you please, since the recent experiments with artificial radioactivity have verified Einstein's equation of 1905 for the conversion of matter into energy and vice versa.

It is interesting to ask what ingredients we need for the construction of a universe in addition to energy. A generation ago we should have required space and time, but now we need only the space-time continuum of Einstein.

We need certain forces within this space-time continuum—the force of gravity, electromagnetic forces, the nuclear binding forces which Tuve and his associates have disclosed, and perhaps the cosmic force of repulsion to account for the expanding universe of Lemaitre. For the study of all these we must turn to physics. And then, perhaps, we shall eventually in the fashion set forth in Einstein's field theory come to regard all of them as manifestations of the space-time field. But whatever decision we may reach eventually, it is apparent that the man without training in physics cannot work successfully in this field and the man without a knowledge of physics cannot hope to have an intelligent understanding of what is being done.

Needless to state, this is a field in which every person, however slight his formal education has been, shows a keen interest. Speaking 2 years ago before the American Association for the Advancement of Science upon the subject of Science and the American Press (11), I sought to trace the factors which accounted for the present-day widespread interest in science. I pointed out that the interest in Einstein's theory of relativity was one of the chief factors in the rapid growth of interest in science immediately following the World War.

I have tried to show so far that a knowledge of physics is necessary for an understanding of the age in which we live, for an understanding of all science, for an understanding of the future, and for an understanding of the universe in which we live. Before concluding

I wish briefly to list certain virtues to be gained from the study of physics. These constitute the remaining cultural values of physics which I want to discuss.

VI

Physics derives its fifth great cultural value from the fact that it teaches the meaning and the value of natural law. This discovery of the existence of the laws of nature has been one of man's greatest triumphs. It has changed his whole intellectual outlook.

To ancient man the universe was a chaos, governed by caprice. In order to explain its phenomena, he found it necessary to people the heavens with a host of minor gods and goddesses, and the mountains and streams with a varied throng of giants, nymphs, and spirits. The occurrence of an eclipse, the appearance of a comet, the gathering of the thunderstorm, and the flash of the lightning were interpreted as the activities of these mythological personages.

Gradually science revealed the order of the cosmos. It taught that the universe was orderly, functioning in response to well-established laws. A corollary of the existence of these laws is the important fact that their willful neglect leads automatically to its own inexorable penalty.

A sixth great cultural value of physics arises from the fact that it teaches precision. Experiments must be planned with precision. Observations and measurements must be precise. Thinking must be definite and logical. This is a lesson well worth learning. The student who carries habits of precision from the physical laboratory to the outside world is the richer thereby.

A seventh great cultural value of physics is that it inculcates a love for the truth and a desire to attain it. I have dwelled at some length upon the present and future applications of physics.

To the scientist, the practical applications have always been secondary. He has sought primarily to understand nature and the universe. Galileo, meditating upon the laws of motion, was trying to understand the workings of nature. He was not thinking of engines and machines. Maxwell, seeking to explain the nature of light, had no thought of the radio. This does not mean that science is contemptuous of its practical uses. The opposite is true. But it does mean that the true scientist is motivated by a higher aim than to make life easier. He wishes also to ennoble and to enrich life. The spirit of science then is, first of all, the wish to know, the urge to seek, the desire to comprehend the universe.

I have sometimes noticed that people who have had no training in science, and therefore have no adequate understanding of its spirit, are confused by this point. I have had them come to me, for example, and ask, "What is the practical use of the Einstein theory?" They understand that scientists regard Einstein as the greatest scien-

tific mind since Newton, perhaps as the greatest scientific mind of all time. But they cannot understand that the scientist venerates the great excursions which Einstein has made into the realm of understanding.

The pursuit of physics, therefore, is valuable in that it will inculcate this point of view in the student and give him a richer outlook upon life.

The eighth great cultural value of physics is its ability to instill the spirit of courage in its students. In this respect physics is one with the other sciences, for the scientist has never been bound by ancient tradition. Copernicus dared to cast aside the Ptolemaic theory though it had dominated man's thoughts for centuries. Vesalius challenged the authority of Galen's anatomy even though it had ruled since the time of the Romans. Scientists did not fear Newton's "Principia" because it was new. They did not flee from Maxwell's electromagnetic theory of light because it was revolutionary.

Twentieth-century scientists have not rejected Planck and Rutherford and Schrödinger and Einstein because their ideas were new. On the contrary, they have rejoiced in each new discovery. This is the courage which the world needs constantly, the spirit to forge ahead, to discover new truths, and to face them when they have been discovered.

The ninth great cultural value of physics is that it instills the spirit of tolerance. The physicist knows that there is no monopoly upon truth. He sees the advance of science as a great cooperative venture of all nations and peoples down through the years. The roll of every science is an international one. Copernicus was a Pole; Tycho, a Dane; Kepler, a German; Galileo, an Italian; Newton, an Englishman. The story is the same today. The theory of Einstein receives its chief verifications at the hands of English and American scientists.

The scientist is tolerant of other men's points of view. Realizing how frequently he must change his own views in the face of new evidence, he is never scornful of the other man's point of view. He realizes how little mankind knows and how much is yet to be learned and the realization makes him tolerant.

The twentieth-century physicist is peculiarly aware of the danger of jumping to dogmatic and sweeping conclusions on insufficient evidence. He is cognizant of the mistake which the nineteenth-century physicist made in concluding that the structure of physics had been completed and that he was justified from that structure in believing in a purely mechanistic universe.

Today, the physicist is aware of the change in our thinking which has been introduced by the Einstein theory of relativity and the Heisenberg uncertainty principle.

Proud as he is of the precision of his experiments and his thinking he realizes that there is, seemingly, today a place where precision breaks down. He knows, from the Heisenberg principle of uncertainty, that he can never measure both the position and the velocity of an electron with exactness. What he achieves in exactness in measuring position, he loses in exactness in velocity, and vice versa.

He is careful not to jump to conclusions too quickly from this fact, although physicists everywhere are studying it. Thus Bohr, for example, has extended this principle to other pairs of measurements and calls these paired quantities "conjugate quantities," and the relationship between the two "complementary."

What may come of this we do not yet know. It is a strange fact indeed that Planck's constant enters the picture at this point. The product of the uncertainty in the case of two conjugate quantities is never less than Planck's constant. It appears to set a natural limit on the exactness of measurement in the atomic world.

The physicist is impressed by many other problems awaiting solutions and for these reasons, therefore, his spirit is the spirit of tolerance.

And finally we come to the tenth great cultural value of physics. This value arises from the fact that the spirit of physics is the spirit of humanity.

Einstein taught us that the observer is always part of the experiment. There is no such thing as setting up an experiment which is a closed system independent of the observer. While the physicist may have thought that possible in the past, nevertheless there never was a time when the physicist forgot human values.

The physicist has always been concerned for the future of mankind. The picture of the scientist as a man who shuts himself away like a hermit in a cave is an unfair picture. There are, of course, such individuals but they are not representative of science.

Let Einstein, whose theories represent man's greatest flight today into the world of the abstract, speak for the scientist's interest in the concrete facts of life. In February 1931, while visiting in Pasadena, he addressed the students of the California Institute of Technology.

"Why does this magnificent applied science which saves work, and makes life easier, bring us so little happiness?" he said. "The simple answer is: Because we have not yet learned to make sensible use of it."

"It is not enough that you should understand about applied science, in order that your work may increase man's blessings," Einstein told the students. "Concern for the man himself and his fate must always form the chief interest of all technical endeavors. Never forget this in the midst of your diagrams and equations."

How much the world needs this spirit today is evident if we turn our attention to recent events in Europe. One cannot resist comparing these words of Einstein's with the words of the man who drove him out of Germany. No doubt you heard his speech of hate, filled with the rattle of the saber and the threat of war, that was broadcast to the world during the Czechoslovak crisis.

A decade ago, H. G. Wells pictured the world in a race between education and destruction. That afternoon, as those words of hate boomed forth from radios everywhere, it seemed as though destruction was about to win.

The dictators of Europe have made no secret of their contempt for democracy and for the freedom of thought and expression which is not only the life of democracy but the life of all science as well.

But will destruction win in the end? I am one who does not think so. I am certain that it will not so long as America remains faithful to its belief in democracy.[3] Therein lies the importance of our educational system for what we teach the young men and women in the schools today will determine the conviction of the citizens of tomorrow.

VII

I have urged in this address that we shape our educational system so that physics be given the position once occupied by the classics as the common cultural bond that united all educated men. In conclusion let me list the 10 cultural values which I have discussed and which, in my opinion, justify this place of honor for the science of physics: (1) Physics is the foundation of the present age and a knowledge of physics is necessary for its complete understanding. (2) Physics seems to be the foundation of every science and all of them can be better understood with an understanding of the principles of physics. (3) The greatest advances of the future will probably be based upon the new discoveries of physics. (4) Our understanding of the cosmos and the picture of the universe given by modern cosmology is founded upon the science of physics. (5) Physics teaches the importance of natural law. (6) Physics teaches precision in observation, experimentation, and deduction. (7) The spirit of physics is the search for the truth. (8) The spirit of physics is the spirit of courage. (9) The spirit of physics is the spirit of tolerance. And finally, (10) the spirit of physics is the spirit of humanity.

I call upon you to have courage and to labor with faith for the future of civilization, for the dawn of that day when the spirit of physics, the spirit of all science, will triumph over the forces of blind hatred, of cruel violence, of bigotry and intolerance. God grant that the dawn may be soon.

[3] Many events have occurred in Europe since the presentation of this paper in October 1938. But I see no reason to change my view on this point.

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NUCLEAR FISSION [1]

By Karl K. Darrow

Bell Telephone Laboratories

Some time this summer the art of transmutation will come to its majority; that is to say, 21 years will have passed since the day it was born in Rutherford's laboratory. Infancy and adolescence for this art have been marked by more stages than we generally count for human children; I propose to distinguish six. Here follows a table of six great events in the story of transmutation, beginning with birth and ending with fission, which, by the way, bears a name that in biology means a certain sort of birth. Each of them lifted the art to a higher level with a broader scope. It is only the sixth and latest which is my topic, but all the others lead up to it, as I will show immediately with the table for my text.

Table of great events in history of transmutation

1919. First success with helium nuclei (energy of activation derived from radium, etc.).

1932. First success with hydrogen nuclei (energy of activation derived from voltage).

1932. Recognition of the liberated neutron.

1934. Recognition of radioactive bodies resulting from transmutation.

1934. Slow neutrons used to produce transmutation, this resulting in radioactive bodies.

1939. Recognition of fission.

Be it said that, in general, transmutation takes place when two nuclei meet and enter into a reaction with each other. They are made to meet by projecting one against the other, and accordingly we speak of one as the projectile and of the other as the target. Transmutation does not occur whenever a projectile comes into the neighborhood of a target nucleus, but only on rare occasions which I will call "lucky hits." There are four principal kinds of projectiles in use for transmutation: Helium nuclei—hydrogen nuclei of two sorts, the light and the heavy—and neutrons. Three stages of my chronology have been marked with their names. The phenomena of fission

[1] Delivered before the National Academy of Sciences at its Washington meeting, April 23, 1940. Reprinted by permission from Science, n. s., vol. 91, May 31, 1940.

are produced with neutrons as the projectiles and uranium[2] as the target, and they therefore belong in the fifth stage of the chronology. But they also depend on the first and the second stages, for neutrons are always obtained by bombarding various targets with projectiles of the first three kinds; and of course they depend on the third, because if the neutron had not been recognized it would hardly now be in use as a tool. Moreover, they depend upon the fourth; the phenomena of fission were first detected because the new-born elements resulting from it are radioactive, and to this day they are often, though not always, observed through this radioactivity. Next it will be noticed that instead of putting fission into the fifth stage, I gave it a line and a stage to itself, and said "recognition of fission" instead of "discovery of fission." This was not in order to compose a three-word poem, but because the phenomena were detected about 4 years before they were properly analyzed; a strange and interesting story, for which, however, there is not space.

Now I make final use of the table in speaking about energy. Everyone has heard so much about the gigantic energies and the huge voltages required for transmutation, that anyone may be pardoned for thinking that transmutation is a process which swallows up enormous quantities of energy—which is strongly endothermic, to use the chemical word. Well, there are many transmutations that swallow energy up without restoring it, but many of them give back much more than they receive. I mean by this simply that whenever a projectile makes a "lucky" hit on a target the total energy of motion of the new-born nuclei is greater than that of the projectile. On balance the experimenter does spend much more energy than is released, because of the amount which he is obliged to squander on projectiles which never make lucky hits; but if one considers only those which do transmute, then their energy may well be smaller and even very much smaller than that which appears on the new-born nuclei. This is what I mean to suggest by using the name "energy of activation" for the energy which hydrogen or helium nuclei must have in order to make them efficient projectiles. It is, however, the release of energy which is one of the spectacular features of fission.

This release of energy is indeed amazing. When the process occurs in any single nucleus there is released—in the form of kinetic energy of the new-born particles—the appalling amount of 175,000,000 electron-volts. To get a notion of what this figure means, remember that in the synthesis of hydrogen and oxygen into water—perhaps the most terrific explosion of all of chemistry—there is released

[2] The lecture was confined to the fission of uranium by slow neutrons. "Fast" neutrons (of energies amounting to a million or millions of electron-volts) produce fission of a different isotope of uranium, and also of thorium and of protactinium.

between two and three electron-volts for each pair of reacting molecules; and in the notorious explosives of industry and war, such as TNT and nitroglycerine, not even so much as that.

Now I have said that fission occurs when a slow neutron impinges on a uranium nucleus, and that an enormous amount of energy is released, and that the resulting new-born elements are radioactive; but I have not yet said what these new-born elements are. This is the second of the astonishing features of fission. All other transmutations have resulted in changing the target element to some other not more than two steps away from it in the periodic table of the elements. In this periodic table, uranium stands at the ninety-second and last place; but the no fewer than 16 different elements thus far identified among the "fission-products" (as they are called) stand in places ranging from the thirty-fifth to the fifty-seventh! What happens in fission is therefore something never before observed—the division of a massive nucleus into two nearly equal fragments. In ordinary transmutations of heavy nuclei, a particle small in both charge and mass pops into a nucleus, and another particle small in charge and mass pops out. In this kind of transmutation a particle of small mass and no charge at all wanders into a uranium nucleus, and the nucleus promptly bursts apart into two pieces not exactly alike indeed but not very different from one another. Fission in biology is the division of a cell into two which are very much alike in size, and this is the source of the name.

As for the fact that fission results in so many different types of nucleus instead of just two, that probably has a double meaning. Many of the radioactive bodies which are observed during and after fission are clearly not the original fragments of the explosions, for after the neutron influx is suspended they increase for a while in amount instead of diminishing. It is clear that these are descendants of the original fission fragments, and the question as to which are really the original ones is at present a very live one. Theory suggests that the initial fragment-pair need not always be the same. One nucleus, on being entered by a neutron, may burst into barium and krypton, another into xenon and strontium, another perhaps into caesium and rubidium. (Note that the members of these element-pairs are so chosen that their atomic numbers add up to 92, which is a way of saying that the entire positive charge of the uranium nucleus must be found upon the two initial fragments immediately after the explosion.) Whatever the initial fragment-pair may be, one at least of its members must be the parent of a long chain of radioactive bodies, and probably both are. This sufficiently accounts for the fact that the fission process produces radioactive elements in a profusion and variety beyond any other which is known.

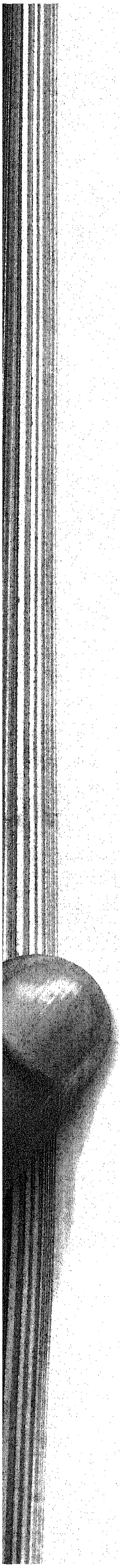
I have saved the most sensational item for the last. Not only is fission caused by slow neutrons, but it produces fresh neutrons among its many products. Could these fresh neutrons produce fission in their turn? Presumably they could; we know of nothing to differentiate them from other neutrons. Could they produce new fissions and these in turn new fissions and so onward in geometrical progression, so that a whole massive piece of uranium might blow up in a sudden explosion of unparalleled fury touched off by so seemingly innocent an event as the entry of a single neutron?

This is perhaps the most important of the unsolved questions of physics. Let us begin by asking after a certain necessary though not sufficient condition. The fissions cannot proceed in geometrical progression, the explosion of the whole mass cannot occur, unless each fission results (on the average) in more than one free neutron to replace the one neutron which is consumed in producing it. Is it so? Well, the few people whose opinions are worth taking agree that it is. They do not agree well as to how many fresh neutrons there are over and above one, but they do agree that there is an excess.

With this as a basis, let us turn the question around. Why has not the great explosion happened as yet, since there are neutrons enough to achieve it?

One reason apparently is, that the fresh neutrons are moving with the wrong speeds when they are released. Fission is performed mainly by very slow neutrons, while the new-born ones are very rapid. But if the piece of uranium were very large, even the fresh neutrons would be slowed down by their repeated collisions with nuclei; and therefore those who are trying to make the explosion, or trying to approach it without quite making it, are heaping up great masses of uranium. If, however, the uranium is mixed with other elements—as in nature it always has been—the neutrons are liable to be captured and rendered harmless by the nuclei of these others. Therefore, the next step is to purify the uranium. This would be easy enough were it not that "purity" in this connection means something more stringent than even chemical purity. Within the last few weeks it has been proved that only one isotope of uranium is sensitive to slow neutrons, and this is a rare one—fortunately, I feel like saying. One must perform a process of isotope-separation in which the two isotopes differ in mass by less than 2 percent, and one is more than a hundred times as abundant as the other. Probably this will take a long time in the doing. If and when it is done, shall we find that human artifice has succeeded in removing or relaxing the last brake provided by nature to impede the slide toward catastrophe? Perhaps not even then, for the rare isotope of uranium may have ways of its own for capturing neutrons and rendering them harmless before the most of

them achieve fissions. Perhaps on the other hand the brakes are easier to relax than the foregoing words imply. Possibly they can be relaxed just a little without letting go altogether, and then there may be available a potent source of power. But at this point I depart from the traditional detachment of the scientist, and express the fervent hope that the mastery of this process, if ever to be achieved at all, will not be achieved until the world is ready to use it wisely.



THE NATIONAL STANDARDS OF MEASUREMENT[1]

By Lyman J. Briggs

National Bureau of Standards, Washington, D. C.

A brief historical background may prove helpful in presenting the present status of our national standards of measurement, particularly those concerned with our customary system of weights and measures. The difficulties under which commerce had been carried out among the Thirteen Colonies, owing to the lack of uniform standards, were probably responsible in part for the provision of the Constitution which delegates to Congress the power "to fix the standard of weights and measures." In the early days of the new Republic, Washington in his presidential message to Congress repeatedly urged the importance of carrying out this constitutional provision; but for 80 years no formal action was taken by Congress to "fix" the standards, save for the adoption in 1828 of a standard Troy pound for coinage purposes.

Not that the subject was ignored. Repeatedly the matter came up for discussion, without definite action. A standard of length which could if necessary be independently reproduced from physical observations repeatedly intrigued the interest of Congress. Jefferson, as Secretary of State, submitted a proposal for a standard of length based upon the length of a uniform cylindrical pendulum beating seconds at sea level at 45° N. latitude. In 1795 President Washington presented to Congress a communication from the Minister of the French Republic suggesting the adoption by the United States of the metric system of weights and measures. This proposal, however, met with little favor. A standard based on the length of one ten-millionth of the earth's quadrant apparently had less appeal from the standpoint of reproducibility than one based on the length of a pendulum beating seconds.

Meanwhile, various State legislatures were imploring Congress to take some action to bring about uniformity; and in 1821, John Quincy Adams, as Secretary of State, urged Congress "to fix the standard

[1] Retiring address of the president of the American Physical Society, presented at the Washington meeting, December 28, 1938. Reprinted by permission from Review of Modern Physics, vol. 11, April 1939.

with the partial uniformity of which it is susceptible at present, excluding all innovations. To consult with foreign nations for the future and ultimate establishment of universal and permanent uniformity." Prophetic words! Not yet has the goal been reached.

In 1830 the Treasury Department, which was charged with the collection of customs, was instructed through a resolution of the Senate to investigate the weights and measures in use in the various customs houses of the country, with a view to bringing about uniformity in the collection of customs. The Secretary of the Treasury gave a broad interpretation to this authority to "investigate," and the outcome was that the various customs offices were supplied, without further action by Congress, with uniform sets of weights and measures. These included an avoirdupois pound of 7,000 grains, and a yard of 36 inches, based upon standards which Hassler, the first Superintendent of the Coast and Geodetic Survey, had obtained in England.

So well pleased was Congress with this solution of its difficulties that the Secretary of the Treasury in 1836 was directed through a joint resolution to deliver to the Governor of each State a complete set of all the weights and measures used by the Treasury Department in the collection of customs. Although no congressional action was taken to legalize these standards, a number of the States adopted them independently, and a groundwork for uniform weights and measures was at last provided.

It was not until after the Civil War that Congress took the first formal step to legalize a system of weights and measures, and this oddly enough did not relate to the weights and measures in common use, but to the metric system, rejected in 1795. The act of 1866 reads as follows:

> It shall be lawful throughout the United States of America to employ the weights and measures of the metric system; and no contract or dealing or pleading in any court shall be deemed invalid, or liable to objection, because the weights or measures expressed or referred to therein are weights or measures of the metric system.

We have thus the anomalous situation in this country of a legalized system of metric weights and measures which is used for scientific purposes, and a customary system of weights and measures which is in common use but has never been formally legalized. When Congress passed the Metric Act in 1866, it realized that the country had no metric standards and accordingly included the approximate equivalents of the metric system in English measure. The length of the meter was defined in inches, even though the length of the inch had never been "fixed." That Congress had in mind only an approximation to the true ratio of the units in the two systems is evident

from the fact that the meter is given as equivalent to 39.37 inches, while the millimeter is rounded off to 0.0394 inch.

The platinum-iridium meter and kilogram, supplied to our Government as a result of its participation in the Metric Convention, provided this country with far better material standards than it had ever had before. Both the meter bar and the kilogram had been carefully compared with the international prototypes, and the coefficient of expansion of the meter bar had been measured. Moreover, they constituted, together with the Troy pound, the only legal material standards possessed by the Government. Accordingly, in the absence of further congressional action, Superintendent Mendenhall of the Coast and Geodetic Survey in 1893 issued the following order:

> The Office of Weights and Measures with the approval of the Secretary of the Treasury, will in the future regard the international prototype meter and kilogram as fundamental standards, and the customary units, the yard and the pound, will be derived therefrom in accordance with the act of July 28, 1866.

It will be recalled that the act of 1866 defines the meter in terms of the inch, and when this is transposed by the Mendenhall order it leads to the incommensurate relation

$$1 \text{ inch} = 0.02540005+ \text{meter}.$$

It is obvious that it is not practicable to lay off this incommensurable decimal fraction on a meter bar, so that this relation defines a theoretical inch rather than one that can be derived with exactness from the meter bar. The inch thus defined is also about four-millionths longer than the British inch, which is determined directly from the Imperial yard.

As a matter of fact, the inch now used for engineering purposes both in the United States and Great Britain, and in 13 other countries as well, is based upon the simpler relation, 1 inch equals 25.4 millimeters exactly. From this simplified relation it is practicable to derive the inch from the meter bar. Furthermore, it is possible to shift from English to metric units on a screw-cutting lathe by the introduction of a gear having 127 teeth. Finally the ratio 25.4 falls midway between the present accepted values of the British and the United States inch. Both countries could adopt this value without disturbing industry in the slightest, because a change of two parts in a million would not be detected in any industrial operation.

To summarize the situation, the United States for 150 years has been using a customary system of weights and measures without "fixing" the standards on which the system is based. A bill was presented to the last Congress with the simple objective of putting the Government's house in order in this respect. The bill provided

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that the inch and the pound should be fixed in terms of the meter and the kilogram, respectively, by means of specified ratios. The ratio proposed for the inch was

$$1 \text{ inch} = 0.0254 \text{ meter.}$$

The bill also carried a supplementary definition of the inch in terms of light waves. This was based upon the value adopted by the International Committee on Weights and Measures for the number of wave lengths of the red radiation of cadmium in a meter, a value which, as I shall show later, is well supported by several independent determinations.

This bill did not come to a vote. Hearings were held by the Committee on Coinage, Weights, and Measures, and the provisions of the bill were found to meet with the general approval of industry. In fact some men directly concerned with precise industrial measurements were inclined to urge that the inch be defined directly in terms of the wave length of the red radiation of cadmium. It seems desirable, however, to have the inch, like the centimeter, based upon an actual material standard. And it is important that this standard should be common to the two systems of units in order that the ratio of the two units of length may be unequivocally fixed.

Opposition to the bill came from an unexpected quarter. The system of plane coordinates which forms the basis for Federal and State surveys is in terms of English units. Now the primary triangulation surveys of the United States Coast and Geodetic Survey are all carried out in the metric system, and in converting these measurements to plane coordinates in feet, the ratio 1 meter= 3937/1200 feet has been used. Those engaged in these mapping operations naturally do not wish to see this procedure changed, and with this viewpoint the National Bureau of Standards is in complete sympathy. An amendment to the original bill has therefore been proposed, authorizing the continued use of the adopted ratio in the conversion of metric geodetic measurements to English units in connection with plane coordinates, elevations, and other map data. This amendment provides full authority to maintain the present procedure in geodetic conversions without sacrificing all the other desirable provisions of the bill. It should be emphasized that the point involved relates only to a computation, namely the conversion into feet of measurements originally carried out in meters in making primary surveys. A change of two parts in a million in the basic value of the inch would not have any effect whatsoever upon any surveys made directly in feet because such surveys cannot approach this order of accuracy. As a matter of fact the hundred-foot tapes calibrated by the National Bureau of Standards are certified to only 1 part in 100,000.

TABLE 1—*Wave length of the red line of cadmium in angstroms* [1]

Date	Authors	As originally given	After (a) correction and (b) adjustment to uniform conditions [2]	Difference from mean
1895	Michelson and Benoit	6438.4722	6438.4691	−.0002
1905–6	Benoit, Fabry, and Perot	6438.4696	6438.4703	+.0010
1927	Watanabe and Imaizumi	6438.4685	6438.4682	−.0011
1933	Sears and Barrell	6438.4711	6438.4708	+.0015
1934–35	Sears and Barrell	6438.4709	6438.4709	+.0016
1933	Kosters and Lampe	6438.4672	6438.4672	−.0021
1934–35	Kosters and Lampe	6438.4685	6438.4685	−.0008
	Mean		6438.4693	±.0012

[1] Sears. J. E., Sci. Prog., vol. 31, p. 209, 1936.
[2] The values originally quoted by the authors are corrected in the fourth column to take account of subsequent conclusions (*a*) regarding the values to be attributed to the standards of length employed, and adjusted (*b*), so far as the information available permits, to uniform conditions of "normal" air—i. e., dry air at 15° C. and 760-mm. pressure, containing 0.03 percent of CO_2.

THE PRIMARY STANDARD OF LENGTH

The national primary standard of length is represented by the platinum-iridium meter bar No. 27. Its use is limited to comparisons with the working standards. A companion bar, No. 21, of identical form and composition, has borne the brunt of extensive comparisons for more than 40 years, particularly in connection with the certification of geodetic tapes for the Coast and Geodetic Survey. The Bureau also owns two other platinum-iridium meter bars of an earlier alloy, one of which is graduated in millimeters.

The stability of these bars in service reflects the wise judgment of those who were responsible for the selection of the alloy from which the prototypes were made. Meter No. 21, which has been used so much and subjected to the thermal shock of innumerable ice baths, has increased in length about 1 micron during its 50 years of service. Meter No. 27, the national prototype, has been certified by the International Bureau of Weights and Measures as follows:

In 1888–89:

No. 27=1 meter−1.50 microns at 0° C.

In 1921–23:

No. 27=1 meter−1.48 microns at 0° C.

These equations indicate that within the limits of measurement the length of meter bar No. 27 has remained invariable in relation to the international prototype for the period covered. This fact alone does not of course preclude the possibility that both bars are drifting. The conclusion that they are not is supported by other intercomparisons and can be examined in another way. During a period of 40 years, various determinations have been made of the length of the meter in terms of wave lengths of the red radiation

of cadmium. The meter bars used in these measurements were compared with the international prototype at the time they were used. Any change in the length of the international prototype would thus tend to be reflected in the derived value of the wave length, in microns, of the red line of cadmium. Table 1 shows no evidence of any systematic drift.

It will be noted that the mean value of the determinations agrees closely with the original value of Benoit, Fabry, and Perot (6438.4696 angstroms), which since 1907 has been used by the International Astronomical Union as the standard to which all spectroscopic wave-length measurements are referred. In view of this fact, the National Bureau of Standards proposed, in the legislative bill referred to above, that the meter and the inch should be given supplemental definitions in terms of wave lengths of the red radiation of cadmium, consistent with the relation adopted by the International Astronomical Union. These supplemental definitions, if adopted, will legalize the direct use of interference methods in the precise determination of the length of gage blocks and similar working standards. The practical value of this procedure cannot be too strongly emphasized.

END STANDARDS

In the past few years the close tolerances placed on the mass production of interchangeable parts has led to the extensive use of precision end gages. These are blocks, usually of metal, with two opposite faces accurately plane, parallel and a specified distance apart, and are used to check various measuring instruments. The extent to which these gages are used can be judged by the fact that more than 50,000 have been tested at the National Bureau of Standards. Using interference methods the surfaces of such gages can be tested and the length determined with greater accuracy than by referring to line standards.

In order to provide the Bureau with end standards of the highest precision, C. G. Peters and W. B. Emerson undertook the construction in 1934 of a series of end standards by direct interference methods, based upon the standard wave length of the red line of cadmium. Fused quartz was chosen for the blanks, because its low expansivity (about one-thirtieth that of steel) removes the necessity of accurate temperature control, and it can be given a high optical polish free from imperfection.

Fifteen blanks 2 cm. square in cross section and 10 cm. long were cut from blocks of optically clear fused quartz. These were annealed by heating to 1,150° C. and then ground and polished to size. Extended measurements of these gages were carried out during a period of 2 years, including measurements made by the International

Bureau, the National Physical Laboratory, and the Physikalisch-Technische Reichsanstalt. From all of these determinations, no measurable change in dimension with time has been detected in any of the quartz gages. The end surfaces were plane and parallel within less than 0.02 micron and the maximum difference in various determinations of the length of any one gage did not exceed 0.02 micron, or 2 parts in 10 million.

In making these standards the decimeter length was chosen because this is about the maximum length for which clear interference rings can be obtained with the sharpest spectral lines. With these lines the number of waves in the path ranges from 300,000 to 400,000. The fractional order can be measured to about 0.01 of a wave length, so it is possible to attain a precision of 1 part in 30 to 40 million in the comparison of two wave lengths and about 1 part in 10 million in the direct determination of a material length standard.

STANDARD WAVE LENGTHS

The internatianal primary standard of wave length is the red radiation of cadmium. The wave length of this radiation as officially adopted by the International Committee of Weights and Measures is 6438.4696 angstroms under specified standard conditions.

Tribute should be paid to the painstaking studies of Michelson 40 years ago that led him to select the red radiation of cadmium as the standard wave length to be evaluated in terms of the meter. All of the spectroscopic work which has been done since that time, including the study of the spectra of helium, krypton, neon, and other gases then unavailable to Michelson has failed to disclose another strong line of superior quality. Two krypton lines are the closest rivals for this honor.

Using the cadmium line as a primary standard, the International Astronomical Union has adopted a series of secondary wave-length standards, including 20 neon lines, 20 krypton lines, and about 300 lines in the iron arc. The measurements of Meggers, Kiess, and Humphreys at the National Bureau of Standards have contributed substantially to the establishment of all of these secondary standards. Most of the neon and krypton standards are known relative to cadmium with a precision of 2 or 3 parts in 100 million, while the precision of the iron standards is about one order less. These standards provide the framework of all spectroscopic measurements.

THE STANDARD PLANE SURFACE

In order to obtain a surface which is optically plane to a high degree of precision, it is necessary to prepare three surfaces, which when tested in pairs in any of the three possible combinations and

in any orientation one to the other show uniformly straight interference fringes. The plane surfaces are actually developed by working these three surfaces one against another in rotation, up to the final stages of polishing.

The standard plane surface of the Bureau is maintained by means of three fused-quartz disks, each 28 cm. in diameter and about 4 cm. thick. One surface of each is a true plane within one-hundredth of a fringe. In other words, these surfaces depart less from true planes than they would if they conformed strictly to the curvature of the earth.

In testing these planes, care must be used to support the disks in such a way as to prevent them from bending under their own weight. The stability of the fused-quartz disks has been most gratifying; no measurable deviation from planeness has taken place in the last 10 years.

ANGULAR MEASURE

Angular quantities must be measured with great precision in carrying out primary geodetic surveys. In determining the errors of a completely graduated circle, the Bureau uses a special comparator which is provided with four fixed micrometer miscoscopes spaced 90° apart around the central rotating table carrying the circle. No standard circle is needed in this case because we are dealing with a closed system. Errors as small as 0.2 second in a 9-inch graduated circle can be measured if the graduation lines are of the highest quality.

The Bureau's circular dividing engine is used mainly for graduating precision theodolite circles for the United States Coast and Geodetic Survey. B. L. Page has graduated solid silver circles 9 inches in diameter to 5 minutes of arc with no error throughout the circle as great as 2 seconds of arc; that is, with no line displaced from its correct position by more than 1 micron.

THE STANDARD OF MASS

The national standard of mass is represented by the cylinder known as the prototype kilogram No. 20. It is made of the same plantinum-iridium alloy as that used in the prototype meter-bars. This national standard was recently taken to Paris for a new comparison with the international prototype. Its certified mass was 0.99999998 kilogram, a change in mass of only 2 parts in 100 million in 50 years. This difference is within the uncertainty of measurement.

Two other standard kilograms, one of platinum-iridium and one of pure platinum, are used as working standards.

STANDARD OF CAPACITY

The standard of capacity, the liter, is established by weighing. It is defined as the volume occupied by a kilogram of water at its maximum density. This volume is unfortunately not exactly 1,000 cubic centimeters as the founders of the metric system had intended. One milliliter=1.000027 cc. The discrepancy is within the error of measurement of most volumetric determinations, but in precise density measurements the unit of volume (cubic centimeter or milliliter) must be specified.

THE STANDARD OF FREQUENCY

The national standard of frequency is maintained by means of seven quartz oscillators, with natural frequencies of 100 or 200 kc./sec. They are carefully protected from external vibration and the temperature and pressure are closely controlled. These oscillators are intercompared constantly and they are also compared daily with time signals from the Naval Observatory. For this purpose, one of the oscillators, with the aid of a submultiple generator, drives a synchronous motor clock which indicates mean solar time.

This group of oscillators serves to control the precision of the standard frequencies of 5,000 kc./sec., 10,000 kc./sec., and 15,000 kc./sec. which are broadcast several days each week from the Bureau's station WWV at Beltsville, Md. These frequencies do not deviate more than 1 part in 5 million from the assigned value.

By means of this service, broadcasting stations throughout the United States are enabled to adhere closely to their assigned frequencies. In addition, the emissions are modulated to give certain standard frequencies in the audible range, which have been found very useful by physicists and engineers. These modulations include a frequency of 1,000 c./sec. as well as sharp 1-second pulses, accurate to 0.00001 second. The broacasting of the standard of musical pitch, 440 c./sec., representing *A* above middle *C*, has also met with wide favor by musicians and laboratory workers alike.

ELECTRICAL STANDARDS

THE STANDARD OF RESISTANCE

Since 1908 the national standard of electrical resistance has been represented by a group of 10 1-ohm manganin coils, the average value of which has been assumed to remain constant. The value originally assigned to each coil was based upon standards certified by the Physikalisch-Technische Reichsanstalt in 1908. When any member of the basic group of 10 coils showed a pronounced tendency to drift in relation to the group, it was replaced by a coil from the reserve group. The NBS "international unit" of resistance is de-

rived from the mean of the values of the resistances of this primary group.

The present evidence is that the mean value of this group has drifted at the rate of about 1 part per million per year since the group was established in 1908. With the hope of eliminating this drift in resistance standards, J. L. Thomas undertook the development of a new precision 1-ohm coil at the National Bureau of Standards in 1928 (1).[2] The manganin resistance after winding was annealed in vacuum at a red heat (550° C.) to remove all locked-up stresses, and special precautions were taken to avoid straining the coil afterward while assembling it in its double-walled annular container. These coils have shown remarkable stability, at least relative to one another. The relative changes within the group have been of the order of 1 part in a million in the past 5 years, compared with similar changes of the order of 10 parts per million in the coils of the older group. In 1932 the 10 coils of the standard group were replaced by coils of the new type.

THE STANDARD OF ELECTROMOTIVE FORCE

The national standard of electromotive force was maintained up to 1937 by a group of 20 saturated Weston cells, with many others in reserve. At that time 9 acid cells which had shown gratifying stability were added, and 3 cells were discarded. The present primary group of 26 cells contains 17 cells that have remained honored members of the group since it was established in 1906. These cells are kept at a constant temperature. The NBS "international unit" of electromotive force is derived from the mean value of the 26 cells of the primary group.

DECISION TO DEFINE THE ELECTRICAL STANDARDS IN ABSOLUTE UNITS

At the conclusion of the work of the Washington conference of 1910 the standards of resistance and electromotive force of the United States, England, France, Germany, Japan, and Russia had been brought into good agreement. But subsequent comparisons showed that the standards were slowly drifting apart, and by 1930 differences as large as 1 part in 10,000 were found in the standards of electromotive force of the different nations, while similar but smaller changes had taken place in the standards of electrical resistance.

A discrepancy also exists between the "international" electrical units now in force and the mechanical units. For example, if the same amount of power were measured first in terms of the electrical units now in use and then in terms of the mechanical units, the differ-

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[2] Numbers in parentheses refer to bibliography at end of article.

ence would amount to approximately 1 part in 5,000 owing to the discrepancy of the units.

For these reasons the International Committee of Weights and Measures decided to replace the present international electrical units with absolute electrical units, the new system to go into effect January 1, 1940.

In order to carry out the wishes of the International Committee it has been necessary for the National Bureau of Standards and the national laboratories of other countries to determine in absolute measure the value of their electrical standards of resistance and electromotive force with the highest attainable precision. A brief description of the Bureau's contribution to this program, which has extended over a number of years, will now be given.

Inductance and current are the most suitable quantities for evaluation in absolute measure because they can be determined to a high degree of precision without involving the measurement of any additional electrical quantity. But the final objective in absolute measurements is the value of the standard of resistance and the standard of electromotive force. The procedure is as follows: (1) The inductance of a coil is computed from its geometrical dimensions and the permeability of the material on which it is wound; (2) this known inductance, when measured experimentally in terms of time and a standard resistor, serves to fix the value of the resistor in absolute measure; (3) current is determined in absolute value from the geometrical dimensions and positions of the coils of a current balance, supplemented by the absolute measurement of the force exerted between the coils; (4) the potential drop across the standard resistor when connetced in series with the current balance serves to fix the value of a standard cell in absolute measure.

THE ABSOLUTE MEASUREMENT OF ELECTRICAL RESISTANCE

Two independent groups at the National Bureau of Standards have been working on the absolute measurement of electrical resistance. Curtis, Moon, and Sparks have used an improved self-inductor with an intermediary capacitance in determining the absolute value of the ohm, while Wenner, Thomas, Cooter, and Kotter have determined resistance in absolute measure by a method using commutative direct current in a mutual inductor.

SELF-INDUCTOR METHOD WITH INTERMEDIATE CAPACITANCE (2)

In this method the self-inductance of an inductor is measured in terms of time and a laboratory standard of resistance. The ratio of the computed to the observed inductance provides the correction factor which is to be applied to the resistance standard to give the re-

sistance in absolute measure. The four inductors used in this investigation were of different dimensions and were wound on nonmagnetic forms of different materials, namely, porcelain, Pyrex glass, and fused quartz. The most recent form consists of a heavy-walled glass cylinder 120 cm. long and 35 cm. in diameter, on the surface of which a very accurate screw-thread was ground and lapped to insure uniformity in the pitch of the helix. The electrical measurements required the use of an intermediary capacitance, so that a resistance was first measured in terms of inductance and capacitance by an alternating-current bridge; then the capacitance was measured in terms of resistance and time by the charge-and-discharge method with a Maxwell bridge. Assuming the capacitance to remain the same under these conditions, it is eliminated between the two bridge equations. Time signals from the United States Naval Observatory were used to calibrate a piezoelectric oscillator which controlled the 100-c./sec. generator.

The most recent work by Curtis, Moon, and Sparks gives the value

1 NBS international ohm = 1.000483 absolute ohms,

which the authors believe to differ from the true value by less than 20 parts in a million.

MUTUAL-INDUCTOR METHOD USING COMMUTATED CURRENT

This method was devised by Dr. Frank Wenner. A direct current is passed through the resistor and through the primary winding of the mutual inductor. The current through the primary of the mutual inductor is reversed at regular intervals without changing the current through the resistor. Another commutator reverses the connections to the secondary of the mutual inductor in such a way that the pulses of induced electromotive force are always in the same direction. This rectified electromotive force is balanced against the constant potential drop through the resistor. A direct-current galvanometer is used to indicate the balance.

The commutators which control the connections in the primary and secondary circuits are mounted on the same rotating shaft along with an inductor generator and a current-reversing generator. Consequently these units all operate strictly in synchronism.

Without attempting to discuss the circuits in detail, it may be said that if the current in the secondary of the mutual inductor is zero at the time the connections are reversed, and if the average value of the current through the galvanometer is zero, then the resistance in absolute measure is four times the product of the speed and the mutual inductance. The precision of the method is limited theoretically only

by the precision with which the speed of rotation of the shaft and the geometrical dimensions of the mutual inductor can be measured.

The shaft is driven by a direct-current motor, automatically synchronized by a current of 1,000 cycles per second; this latter frequency is controlled by the primary quartz frequency-standards in the Bureau's radio laboratory. Over periods of an hour or more the frequency of the control current is constant and known to 1 part in 10,000,000, while the speed of rotation, averaged in the way in which it affects a deflection of the galvanometer, is uniform within a few parts in 1,000,000.

The absolute determination of the ohm by Wenner, Thomas, Cooter, and Kotter gives the relation

1 NBS International ohm=1.000485 absolute ohms.

THE ABSOLUTE DETERMINATION OF THE AMPERE

H. L. Curtis and R. W. Curtis (3) have made a new determination of the ampere in absolute measure, employing with some modifications the current balance originally used by Rosa, Dorsey, and Miller for this purpose in 1911. The most important modification was the use of coils in which the current distribution closely approached that assumed in the theoretical derivation of the force. The value in absolute amperes of the current in the coils of the balance was computed from the dimensions and positions of the coils, the permeability of the material and the electromagnetic force between the coils, the latter being measured in local gravitational units.

In such measurements, we must know the absolute value of the local acceleration of gravity, and Heyl and Cook (4) have recently completed this determination at the National Bureau of Standards using pendulums of fused silica. They found, at the Bureau station:

$$g=980.08 \text{ cm. sec.}^{-2},$$

which indicates that the absolute value of gravity at Potsdam, heretofore generally accepted, is about 2 parts in 100,000 too large.

The current through the balance coils was measured simultaneously (1) in absolute value by means of the balance and (2) in "international" amperes as determined by the potential drop across a standard resistor in series with the balance coils.

The result of the most recent measurements with balance coils of improved design is:

1 NBS International ampere=0.999852 ampere (absolute).

THE INTERNATIONAL TEMPERATURE SCALE

The thermodynamic scale of temperature introduced by Lord Kelvin has long been accepted by physicists as the ideal temperature

scale. However, the experimental difficulties incident to the practical realization of the thermodynamic scale by means of the gas thermometer and the consequent discrepancies that arose in the temperature scales used by different nations led the national laboratories of Germany, Great Britain, and the United States in 1911 to undertake the unification of their temperature scales. This culminated a quarter of a century later in the adoption by the International Committee of Weights and Measures of the International Temperature Scale (5).

This scale conformed with the thermodynamic scale as closely as knowledge permitted at the time, and was designed to be definite, conveniently and accurately reproducible, and to provide means for uniquely determining any temperature within the range of the scale. It is based upon six fixed and reproducible equilibrium temperatures to which numerical values are assigned; namely, the oxygen point (−183° C.), the ice point (0° C.), the steam point (100°), the sulfur point (444°), the silver point (960.5°), and the gold point (1063°). Intermediate temperatures are determined by means of interpolation instruments calibrated according to a specified procedure at the fixed temperatures.

From the oxygen point to 660° C. the temperature t is deduced from the resistance of standard platinum resistance-thermometers; from 660° C. to the gold point, by means of a standard platinum versus platinum-rhodium thermocouple; and above the gold point, from Wien's law by means of the intensity of blackbody radiation, measured by an optical pyrometer.

The International Temperature Scale was adopted with the understanding that it was susceptible to revision and amendment. The first meeting for the consideration of possible revisions will be called in Paris in June 1939.

There is great need for the official extension of the scale from the oxygen point down to the triple point of normal hydrogen (−260° C.). At present the National Bureau of Standards maintains the scale in this region by means of a group of well-seasoned resistance thermometers. Hoge and Brickwedde (6) have shown the feasibility of establishing a number of fixed points in this part of the scale, represented by the equilibrium states of coexisting phases of pure substances. With these points once established, resistance-thermometers need be used only for interpolation.

Another matter that requires consideration is the value of c_2 in the radiation equation. The value now specified in defining the International Scale is $c_2=1.432$ cm. degrees. More recent determinations indicate that this value should be increased to 1.436 cm. degrees. This would decrease the present value of the platinum point by about 3° C.

RADIATION STANDARDS

THE INTERNATIONAL ROENTGEN

The international roentgen is the quantity of X-rays that will liberate one electrostatic unit of charge from 1 $cm.^3$ of air by ionization under specified standard conditions. It is realized at the National Bureau of Standards by means of a standard ionization chamber developed by Taylor and Singer (7), which has now been adopted as the ionization standard of six other countries besides our own. The calibration of X-ray dosage meters in roentgens is carried out by means of this standard chamber.

RADIUM STANDARDS

Radium is certified by the National Bureau of Standards in terms of the weight of radium element, but the measurement which is actually made is the determination of the ratio of the gamma-ray intensity of the specimen to that of a radium standard. The Bureau has three primary radium standards carrying certificates from the International Radium Commission. The first of these (International value 15.44 mg.) was prepared by Madame Curie (1913) and the other two (International values 38.10 mg. and 20.36) by Hönigschmid (1936) from radium chloride of high purity. The Curie standard when corrected for decay is in accord within 0.1 percent with the values assigned by Hönigschmid to the standards he prepared. Radium standards must be systematically corrected for decay. The initial rate of decay is about 0.043 percent per year.

STANDARDS OF RADIANT FLUX

The National Bureau of Standards maintains standards of radiant flux, based upon absolute measurements by Coblentz (8). Lamps are now supplied by the Bureau with certificates giving the total radiation in microwatts per square centimeter at a specified distance from the source.

THE STANDARD OF BRIGHTNESS

International agreement has now been reached regarding the adoption of a primary standard of brightness, defined as the intensity of the radiation from the interior of a blackbody at the temperature of pure platinum at its freezing point. This standard was originally proposed by Waidner and Burgess in 1910 but was first actually realized at the National Bureau of Standards in 1931 by Wensel, Roeser, Barbrow, and Caldwell (9), following the development of the thoria crucible at the Bureau.

Using the same device operated at the freezing points of rhodium and iridium in addition to platinum, Wensel, Judd, and Roeser (10) established an accurately reproducible scale of color temperature. This scale is made available to the public through the distribution of color-temperature standards in the form of tungsten-filament lamps.

Comparison of the blackbody standard with the present international candle as maintained by groups of carbon-filament lamps showed that the brightness of the new standard was about 58.9 international candles per square centimeter. However, a uniform procedure has not been followed internationally in the step-up from the yellower sources to the modern tungsten lamps, and E. C. Crittenden found that a better agreement with present practice would be reached by defining the brightness of the standard blackbody radiator as equal to 60 candles per square centimeter. Other national laboratories have agreed to the Bureau's suggestion to adopt this value, and this recommendation has been approved by the International Committe of Weights and Measures. In stepping up from the blackbody standard to tungsten lamps, it is proposed to use the luminosity factors recommended by Gibson and Tyndall (11) of the Bureau staff in 1923, and later adopted by both the International Commission on Illumination and the International Committee of Weights and Measures. At last we have an international primary standard of brightness.

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THE RISE OF THE ORGANIC CHEMICAL INDUSTRY IN THE UNITED STATES [1]

By C. M. A. STINE
Vice president, E. I. du Pont de Nemours & Co., Wilmington, Del.

[With 4 plates]

The results of the rapid development of the organic chemical industry in the United States have been so far reaching and are so obvious as to require no proof that there is in existence today a great industry showing a phenomenal growth in the last two decades. It is young and extremely vigorous; its fruits are of such beauty and utility that I am satisfied as to its continued cultivation and development.

Let me mention two of the most important and tangible results of the development of the organic chemical industry of the United States; first, the fostering of a tremendous expansion in the training of research workers in our universities, and the promotion of a great and widespread interest in organic research. This has had significant repercussions in practically all fields of research, leading to expansion and intensification of effort and to results of enhanced value.

The second has been the tremendous contribution to national self-sufficiency in this country which the rise of our organic chemical industry has made. There is good ground for believing that self-sufficiency very definitely makes for peace. Through research and synthesis we have obtained methods of preparing certain materials of organic origin which are not available in this country because of limitations of soil or of climate, or for some other reason inherent in our national economy. For instance, we are not able to grow rubber in the United States, and even though climatic conditions were favorable we should still be unable to harvest it at the low costs which now prevail in the rubber-producing countries. Research and the reduction to practice of the results of this research have not

[1] An address delivered on the occasion of the presentation to Dr. Stine of the Perkin Medal of the Society of Chemical Industry, at the Chemists' Club, 52 East 41st St., New York City, on the evening of January 12, 1940. Reprinted by permission from Industrial and Engineering Chemistry, vol. 32, No. 2, February 1940.

only contributed to our eventual independence in respect to certain natural fibers and in respect to rubber, but also have placed at our disposal methods for the manufacture of almost unlimited quantities of liquid and gaseous hydrocarbons from the vast natural resources of coal with which nature has endowed us. Economic factors, of course, have a large bearing upon fixing the date of a complete independence of natural sources of supply of oil, rubber, or some types of natural fibers.

So it is not so much my task to demonstrate that a great productive organic chemical industry has developed in the United States over the last two decades, but rather it is my task to trace a few of the more important lines which the industry has followed in its development and, perhaps, to reinforce the observations with a few figures, if I may do so without becoming tiresomely statistical.

Contrary to popular belief, America had a substantial chemical industry prior to the World War. As early as 1865, American chemical production had a valuation of some $60,000,000.[2] In 1910 the United States produced three times as much sulfuric acid as Germany, and our production of alkalies was double that of England.[2] The value of our chemical and allied products in 1914 was in excess of 2 billion dollars.[3]

Although America experienced a more or less steady growth of chemical manufacture from early colonial days down to the World War, this 300-year period was characterized for the most part by developments in inorganic chemistry. I should emphasize the differentiation between inorganic and organic chemistry. The fateful World War period served to disclose our woeful lack of manufacturing facilities for many essential materials of an organic chemical nature. This intolerable situation gave impetus to the research which has characterized the quarter of a century since 1914—research which has culminated in the greatest organic chemical industry in the world.

This new industry is a substantially 100 percent American development. It was neither borrowed nor transplanted from Europe. It was conceived by American men and financed by American money.

The brains which directed the research were American brains, and the methods employed in building up the industry were American methods. This does not mean that we have not profited from foreign developments and foreign experience. We have, and we gratefully acknowledge such assistance.

Without an unwavering faith in research, the organic chemical industry would not exist today. A clear vision of the possibilities of such an industry was also essential, and likewise "patient money,"

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[2] Haynes, Williams, Men, money and molecules, pp. 71 and 57, 1936.
[3] Abstract of the U. S. Census of Manufactures, 1914, p. 168.

as the late John E. Teeple so aptly expressed it. I cannot speak for the entire industry, but I do know that during the early years in which the du Pont Company conducted intensive work with dyestuffs and other organic chemicals, an outlay of more than $40,000,000 was made—without 1 cent of profit being realized. This outlay represented plant investments, operating losses, and research expenditures. I am quite sure our experience was not unique.

During the past 25 years research has come to be recognized as the most valuable tool available to the chemical industry. It is the only tool with the power to create. While reliable data for the entire industry are not available, Fortune Magazine reports that American Cyanamid, Dow, du Pont, Eastman, and Monsanto spent $12,600,000 on research in 1937, corresponding to about $2.80 of each $100 of their aggregate net sales.[4] Fortune's figure is, I believe, conservative, since in recent years the research bill of the du Pont Company has been an appreciably greater ratio of sales.

The industry as a whole is reported to have spent $20,000,000 for research in 1937, corresponding to an estimated $2.25 out of each $100 of sales of inorganic chemicals, and $4.30 out of each $100 of sales of organic chemicals.[5] Only the steel and petroleum industries, spending an estimated 50 and 40 cents, respectively, per $100 of sales,[4] are reported as having research expenditures at all commensurate with those of the chemical industry. But let us not be puffed up with pride over our national state of mind—research expenditures by American industry as a whole, if estimated correctly at $250,000,000 a year, are lower than the nation's annual bill for cosmetics by about $150,000,000.[6]

The rise of our organic chemicals manufacture might be portrayed either by cold statistics, or by showing the important role of American organic chemicals today in our whole industrial and everyday life. For the most part I propose to follow the latter method, but for the benefit of the statistically minded a few production figures might be given. It might also be interesting to show how prices have been reduced as production increased.

In 1914 this country produced only about 10 percent of the dyes consumed, and even that small proportion was based almost wholly on imported intermediates. In 1938, by contrast, we produced about 96 percent of the dyes consumed in this country, and had an export balance of some 5 million pounds. Our production of other organic chemicals in 1914 was insignificant, so for data on which to base further comparisons, let us consider 1919, when the manufacture of

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[4] Fortune, March 1939, p. 58.

[5] Chem. and Metallurg. Eng., September 1937, pt. 2, p. 545.

[6] Readers Digest for March 1939, p. 18, gives the approximate figure of $400,000,000 for our 1938 cosmetics bill.

organic chemicals was really getting under way. During the 19-year period ending with 1937, we find such approximate average annual increases in production as the following: Coal-tar medicinals, 6 percent; total coal-tar finished products, 18 percent; photographic chemicals, 22 percent; flavors and perfume materials, 29 percent.[7] Bear in mind that these percentages are for average annual increases, not for the increase over the entire 19-year period. It should also be borne in mind that during the same period the average annual increase in population was only about 1.25 percent.

Organic chemicals of non-coal-tar origin were somewhat slower getting under way, but during the 17-year period 1921–37, production of non-coal-tar organics, including synthetic methanol and other alcohols, acetic acid, acetone, and various amines, showed an average annual increase of 685 percent.[7]

The astounding rate of growth indicated by these figures is the more impressive by comparison with corresponding figures for certain other manufactured products, including representative staple inorganic chemicals. The average annual increase in sulfuric acid production, for example, was only about 2.3 percent for the same period; soda ash, 5.3 percent; woven cotton goods, 2.6 percent; pig iron, less than 1 percent; steel and cement, each about 2.4 percent; while lumber and newsprint paper each declined about 1.3 percent annually. Automobile production showed an average annual increase of 9.6 percent, and concurrent with this increase in automobile production crude petroleum showed an average annual increase of 12.5 percent. It is significant that while automobile production showed an increase of 9.6 percent, automobile casings and tubes showed an increase of only 3.2 percent.[8] This apparent discrepancy means, of course, that the tires made around 1937 were much superior to those made around 1919, a superiority due in part to improved rubber chemicals, including organic accelerators and antioxidants, which added greatly to the life of tires and tubes.

Price reductions during this 1919–37 period were equally as phenomenal as production increases. The average value of total coal-tar finished products, for example, declined from \$1.02 a pound to 41 cents; photographic chemicals from \$3.16 to \$1.05; flavors and perfume chemicals from \$2.27 to \$1.02; and coal-tar dyes from \$1.07 to 55 cents a pound.[9] Certain inorganic chemicals which find wide application in the manufacture of various organic products likewise

[7] Figures based on data from Census of Dyes and Coal-Tar Chemicals (U. S. Tariff Commission) for years indicated. Average annual increase arrived at by dividing total increase by number of years in period.

[8] Figures based on data from Abstract of Fourteenth U. S. Census (1920) and Census of Manufactures (1937), except pig iron and steel figures which are based on data from Mineral Resources of the United States, 1919, pt. 1, and Minerals Yearbook for 1939.

[9] Census of Dyes and Other Synthetic Organic Chemicals.

showed important price reductions during this period. Sulfuric acid, for example, declined about 31 percent, and caustic soda nearly 45 percent.[10]

Even during the period 1927–37, after much of the necessary pioneering research had been done, we still find marked reductions in the price of organic chemicals. During this decade acetic acid dropped from $3.38 to $2.43 per hundred pounds; methanol, from 67.5 to 33 cents a gallon; and formaldehyde from 10.33 to 5.75 cents a pound.[11] Coal-tar chemicals likewise underwent substantial price reductions during this more recent period. Phenol, for example, widely used in the manufacture of plastics, dropped from 17.5 to 13.25 cents a pound,[11] and coal-tar medicinals from $1.92 to 96 cents a pound,[12] a decline of exactly 50 percent. Synthetic organic chemicals of non-coal-tar origin dropped from 18 cents a pound to 10 cents.[12] Likewise during this period we find marked price reductions in certain inorganic chemicals widely used in the organic chemical industry. Anhydrous ammonia, for example, declined from 7.5 to 4.5 cents a pound, and chlorine from $4 to $2.15 per hundred pounds.[11] By way of contrast, the average price of all chemicals during the 1927–37 period declined only about 10 percent.[13]

To the statistically minded, the above figures bear eloquent witness to the rise of our domestic organic chemical industry, but cold statistics cannot portray the vital national significance of this industry. When all is said and done, it is the broad, general significance of a development that is of primary interest both to the chemist and to the layman. Let us accordingly consider the relation of the organic chemical industry to other industries, and attempt to visualize what this development means in terms of our everyday existence. The complete story cannot, of course, be told here, but a high-spot survey should be sufficient to show the degree of our present dependence upon organic chemicals. It is not exaggerating, I believe, to say they have fundamentally affected our national economy. They have promoted the development of other industries, which in turn have provided new jobs for our increasing population; greatly stimulated many of our older industries; provided the farmer with improved weapons with which to combat insects and plant disease; promoted comfort and health; brought to the masses of the American people many of the good things of life which formerly were to be had only by the relatively well-to-do; and promoted national self-sufficiency and security.

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[10] U. S. Census of Manufactures.
[11] Ind. and Eng. Chem., June 1938, p. 601.
[12] Census of Dyes and Other Synthetic Organic Chemicals.
[13] Survey of Current Business, 1938 Supplement (U. S. Department of Commerce), p. 13.

NEW INDUSTRIES AND NEW JOBS

This new industry for organic chemicals manufacture has not only provided jobs directly for thousands of workers, but also has indirectly opened up countless additional thousands of new jobs by providing the chemicals which have contributed to the development of new industries. As we have seen, these chemical raw materials, as it were, have been supplied at steadily reduced prices. The dyestuffs, pharmaceuticals, and plastics industries might be cited by way of illustration. To be sure we have made some products in these classifications for many years, but in a larger sense they represent new industries.

Plastics of the nitrocellulose type were, of course, made by Hyatt in 1869, but how could our modern plastics industry operate without a plentiful supply of such organic chemicals as the acetic acid used in the manufacture of cellulose acetate plastics; synthetic camphor, used in the manufacture of nitrocellulose plastics and motion picture film; and the phenol, formaldehyde, and urea used in a variety of well-known and widely used plastics?

The importance of camphor is indicated by the fact that more than a half-million pounds is used each year in motion picture film alone. As you doubtless know, camphor was the instrument of a foreign monopoly 25 years ago, but in recent years American chemists have shown that camphor chemically identical with that from the camphor trees of Formosa can be economically made from pinene, derived from southern turpentine. Today, the du Pont Company is making more than half of the total domestic consumption of this important product, and in an emergency additional plant equipment could be installed to provide our entire needs. As recently as 1920, refined imported natural camphor reached $3.55 a pound. In contrast, refined synthetic camphor is selling for around 48 cents a pound, while the technical grade used in plastics and photographic film sells for only about 35 cents a pound.

Likewise imported urea cost in 1920 about 57 cents a pound, corresponding to over $1,100 a ton.[14] Today urea of equal or better quality, made at Belle, W. Va., from carbon dioxide and ammonia, sells for $95 a ton. Practically all of the urea now consumed in this country comes from this domestic source of supply.

In addition, the organic chemical industry has brought out materials not hitherto commercially available, which have found application in wholly new types of plastics. I shall cite only one illustration—namely, methacrylic acid, on which are based such products as the new sparkling "Lucite" methyl methacrylate plastic

[14] Oil, Paint, and Drug Reporter, February 26, 1931, p. 50.

which, because of its toughness, beauty, and optical properties, is finding application for a variety of purposes.

Verily our modern plastics industry is a child of the organic chemical industry, and the same holds equally true in other fields of manufacture—medicinals and dyestuffs in particular.

Still other organic chemicals, synthesized to meet definite specifications, as it were, have likewise promoted the development of new industries. The "Freon" fluorinated hydrocarbons are an excellent illustration of such "built-to-specification" products. Because "Freon" is not only an excellent refrigerant, but also nonpoisonous, nonexplosive, and nonflammable, it has given great impetus to the air-conditioning industry, and is widely used today in the air-conditioning units of theaters, hotels, office buildings, trains, and a rapidly increasing number of homes.

STIMULATION OF OLD INDUSTRIES

Products of the organic chemical industry have not only aided in the development of new industries, but also contributed greatly to many of our older industries, such as the manufacture of rubber goods, textiles, paper, automobiles, refrigerators, petroleum products, perfumes and flavors, and explosives.

Of interest in a number of different manufacturing operations are the synthetic alcohols, organic acids, esters, ethers, halogenated hydrocarbons, ketones, urea and substituted ureas, and many other types of aliphatic compounds which in recent years have become commercially available. These materials find wide industrial application, serving as solvents, plasticizers, blending agents, waxes, antifreezes, raw materials for the manufacture of commercial dynamites, degreasing solvents, dewaxing agents, extraction media, and solvents for purification by recrystallization. The listing of only a few developments of this type must serve to suggest the whole fascinating picture of organic chemical synthesis in aliphatic chemistry—a field which is still in the very earliest stages of its development.

Of outstanding importance in the manufacture of rubber goods are the new and improved organic accelerators, antioxidants, sun-checking inhibitors, and agents which nullify the destructive influence of slight traces of copper. The fact that today's automobile tires give some 25,000 miles of service in comparison with 5,000 miles only a few years ago is due in no small degree to the use of such organic rubber chemicals.

Synthetic rubberlike materials developed within the past few years have likewise been accorded a hearty welcome by fabricators of rubber goods. Although these "chemical rubbers" are different in composition from natural rubber, the physical properties of certain of

these synthetic materials are very similar to those of rubber, and at least one of these new materials—neoprene—has qualities not found in the natural product, including resistance to oils, greases, chemicals, sunlight, and oxygen. These chemical rubbers are accordingly filling hundreds of needs that natural rubber cannot fill.

And the fact must not be overlooked that this chemical rubber, which can be used for practiaclly every purpose to which natural rubber is put, is based on domestic raw materials of which we have an abundance—coal, limestone, and salt.

The important role played by synthetic dyestuffs in the textile industry is so well recognized as to warrant no discussion.

Of the numerous other synthetic organic chemicals which find application in the manufacture and finishing of textiles, particular mention should be made of the fatty alcohol sulfates used as detergents. Certain of these materials are very similar to ordinary soap in detergent properties, except that they function as well in hard water as in soft water. Such compounds are accordingly a boon to textile finishers, particularly in hard-water regions. Other fatty alcohol sulfates, and also certain alkyl sulfonates, find application as wetting agents to facilitate dyeing and other textile operations. Still other related materials are used as textile softeners, to impart a pleasing "feel" to fabrics.

Mention should also be made of improved moth repellents, mildew inhibitors of the type of salicyl anilide, and water-repellent finishes. Of particular interest is the recently developed "Zelan" durable water-repellent finish. The base of this new finish—a quarternary ammonium salt—becomes so firmly bound to textile fibers, either chemically or physically, that it is not removed by repeated laundering or dry cleaning.

No discussion of the role of organic products in the textile industry would, of course, be complete without reference to rayon, of which this country produced some 288,000,000 pounds in 1938, and the more recently developed products such as "Vinyon" and the synthetic polyamides known as nylon. Nylon had its origin in the work on polymerization and giant molecules, subjects investigated as part of the fundamental research which I initiated some 12 years ago, and which I am happy to say is still being viogrously prosecuted. Most of you, I feel sure, have heard of nylon, and know that dibasic organic acids and diamines are among the intermediates to be used in making this new family of materials. Note that I say "family" of materials, since many different nylons are possible.

Many of you have probably heard that one of the more promising outlets for nylon will be in the manufacture of yarn which, because of its high strength-elasticity factor, will be used in fine hosiery.

The production of nylon yarn on a limited scale was started early this month, and small commercial shipments will be made in February 1940. It is anticipated that within the next few months full-fashioned nylon hosiery will be on general sale.

Nylon is now on the market in the form of bristles for toothbrushes and other toilet brushes, and also for certain types of industrial brushes. It is also on the market in the form of sewing thread, fishing lines and leaders, and surgical sutures. It is said to offer numerous advantages over natural gut sutures. Perhaps other lines of manufacture wholly new are still cradled in this chemical nursery.

I am sure that all of you are more or less familiar with the role of organic chemicals in the automobile industry. The story has been told many times, and I shall accordingly not dwell on it at great length. Nitrocellulose lacquers, developed around 1921, probably represent one of the greatest chemical contributions to the automobile industry. By cutting down the finishing time from 4 to 9 days to as many hours, mass production was greatly facilitated. In an attempt to reduce finishing time with the old orthodox enamels, durability had been sacrificed, but the nitrocellulose lacquers are both quick-drying and durable.

The development of synthetic rubberlike materials was previously mentioned. Automobile motors are frequently mounted on blocks of neoprene or other "chemical rubber," to minimize chassis vibration. Natural rubber used for this purpose deteriorates rapidly under the influence of grease and oils with which it may come in contact. Because of its resistance to grease and oils, neoprene does not undergo this deterioration, and is accordingly well suited for the mounting of motors and some 50 other special uses about the car.

The recent development of polyvinyl acetal plastics has a very direct bearing on the automobile industry. For many years safety glass for the windows and windshields was made with an interliner of nitrocellulose or cellulose acetate plastic, but last year it was found that an interliner of a certain type of polyvinyl acetal plastic has definite advantages over the cellulosic plastics. This new plastic is not only extremely tough and elastic at ordinary temperatures, but retains its toughness and elasticity at very low temperatures. It is for this reason that the polyvinyl acetals—products of the organic chemical industry—make possible the safest safety glass ever made.

Organic plastics find other applications in the automobile industry. Plastics are used in the distributor head, on the instrument board, and constitute various articles of internal decoration and utility such as the knob of the gear-shift lever and the steering wheel. It is of interest that these plastics are not only organic products themselves, but frequently demand other organic chemicals to modify their inherent

physical characteristics—plasticizers, for example, to facilitate molding operations. Still other organic chemicals are used in the lubricants and in motor fuel, but these will be covered in connection with petroleum products.

Mention was made of "Freon" in connection with air-conditioning. Because these new fluorinated hydrocarbons are absolutely safe, they are now widely used not only in air-conditioning, but also in domestic refrigerators as well. Another important class of organic materials used by manufacturers of mechanical refrigerators are the oil-modified alkyd resin baking enamels. This new type of finish has to a considerable degree displaced porcelain finishes. This shift from porcelain to alkyd resin finishes has resulted in a marked decrease in cost of production, which in turn is reflected in reduced prices to the ultimate consumer. Alkyd resin finishes of the type used on refrigerators are characterized by a high degree of toughness, resistance to grease and stains, and by excellent color retention. Related alkyd resin finishes are widely used for interior woodwork and for certain specialty outdoor applications—metal-protective paints in particular. Alkyd resin finishes are also being used on several types of automobiles—both passenger cars and motortrucks—on ships and railway cars.

One of the principal intermediates used in making the alkyd resin finishes is phthalic anhydride, made by the oxidation of naphthalene. Whereas phthalic anhydride was more or less a laboratory curiosity in 1917, selling for about $6 a pound,[15] some 43,000,000 pounds were made in 1937, and the estimated production for 1939 was of the order of 60,000,000 pounds. Currently the price of this important coal-tar intermediate, the principal outlets for which are in the manufacture of alkyd resins and certain types of dyes, is around 15 cents a pound. Within recent years a new and greatly improved method has been developed for the preparation of phthalic anhydride, involving oxidation of naphthalene in the vapor phase, and it is largely due to this improved method that alkyd resin finishes are available today at prices which enable them to compete with the so-called orthodox finishes.

I have taken a very personal interest in this new type of finish, since much of the pioneering work on alkyd resin finishes was done under my direction. Some 15 years ago when my attention was first called by Dr. Whitney to resins made by the General Electric Co. through the interaction of polyhydric alcohols such as glycerol, and polybasic acids such as phthalic anhydride, it occurred to me that resins of this type might find application in nitrocellulose lacquers to replace imported natural resins such as damar. It likewise occurred to us about the same time that resins of the same general type, suitable for use in paints and varnishes, might be made through the simultaneous reac-

[15] Oil, Paint, and Drug Reporter, 1918 Year Book, p. 127.

tion of a polyhydric alcohol, a polybasic acid, and a monobasic fatty acid derived from drying oils such as linseed or Chinawood oil. A program for research was accordingly mapped out, and about 1925 or 1926 work was started. First and last, we spent more than half a million dollars on research directed to the development of variously modified alkyd resins, but I am happy to say that the fruits of this work have been such that we have had no occasion to regret spending this rather large sum.

Synthetic organic chemicals find numerous important applications in the manufacture and use of petroleum products. As you know, cracking processes had the effect of doubling our oil reserves as far as gasoline is concerned. On the other hand, however, cracked gasoline on storage has a tendency to develop gums which would lead to clogging of the motor and fuel lines. Through the use of certain organic chemicals, however, this tendency to gum formation is substantially eliminated. The amount of an antioxidant such as isobutyl-para-aminophenol necessary to stablize cracked gasoline so that it may be stored for several months, or even a year, costs only 2 or 3 cents to the barrel of gasoline. This is of interest not only to the motorist, but also to the refiner, since before the advent of gum inhibitors it was not unusual for cracked gasoline which had been stored for some time to require redistillation before it was sold.

Likewise of interest to manufacturers of petroleum products are the organic chemicals used in lubricants. Small amounts of a chemical such as the esters and nitriles of long-chain fatty acids increase the "oiliness" of a lubricating oil—that is, the coefficient of friction is lowered. In addition it is claimed that these "oiliness" promoters reduce the wear on moving parts, thereby minimizing shut-downs and repair bills.

We have also what are known as extreme pressure lubricant bases which cause a film of lubricating oil to be "tough." Several types of organic materials are used for this purpose, including halogenated and phosphated oil compositions, lead soaps, and sulfurized oils. When present in oils and greases in amounts as low as 1 percent, these extreme-pressure lubricant bases make it possible for a bearing or gear to withstand tremendous pressures without the bearing surfaces actually touching one another, and possibly "seizing." For the lubrication of the hypoid gear, for example, which is used in the differential of most of the cars now being made, it is absolutely necessary that an extreme-pressure lubricant base be used in conjunction with the lubricating oil, since the peculiar frictional forces that obtain in this improved gear would squeeze out or rupture the film of any untreated oil, leaving the metal surfaces in direct contact. The presence of a suitable extreme-pressure lubricant base insures that a film of oil will always separate and protect the bearing surfaces.

Many other illustrations might be cited to show how our older industries have been aided through products or techniques having their origin in the organic chemical industry, but I shall mention only a few more.

In the manufacture of perfumes, materials known as fixatives are used, one function of which is to make the odor more lasting. Until a few years ago, all fixatives were of animal origin, such as the musk from a species of deer found in Tibet. The characteristic ingredient of natural musk, if it could be had in a perfectly pure state, would probably be worth its weight in gold several times over, but within recent years synthetic musks have been developed, and at least one of these new organic compounds is substantially identical with the characteristic ingredient of natural musk. All sell at only a fraction of the cost of the natural product. Moreover, the chemist has synthesized certain floral odors which cannot well be recovered from flowers. Perfumes having the true scent of lilac or lily-of-the-valley, for example, were not to be had until the chemist synthesized these elusive and delicate odors. Wholly new odors have also been synthesized, but it should be understood that, for the most part, synthetic perfume chemicals supplement rather than displace natural floral odors. High quality perfumes are usually a skillful blend of the natural and synthetic.

The close relationship between organic chemicals and the explosives industry is well illustrated by some of my own early experiences. One of my first assignments after becoming affiliated with the du Pont Company in 1907 related to the manufacture of ammonium nitrate, used in certain types of dynamite. In particular we sought to find the cause of repeated fires which occurred on evaporating the neutralized ammonia liquors. Since this was before the days of synthetic ammonia, the ammonia liquors came from byproduct coke ovens, and were originally bought on the basis of their ammonia content. While they were analyzed for various inorganic constituents, no attention whatever was paid to the possibility of organic matter being present. To make a long story short, I carefully investigated the ammonia liquors and found relatively large amounts of volatile tars. When the liquors were neutralized with nitric acid, some of these tars were partially nitrated. When the neutralized liquors were concentrated by evaporation, the deposit of unstable nitrated tarry matter along the margin of the hot ammonium nitrate liquors often ignited spontaneously, and it was this that had caused some disastrous fires. I thereupon worked out a quantitative method for the quick determination of the total tarry content of ammonia liquors, so that a specification as to tarry content could be incorporated in connection with the purchase of ammonia liquor.

Another early assignment was a study of the nitration of toluene in the production of a mixture of nitrated toluols used to lower the

freezing point of dynamite. This work led me to a study of various nitro derivatives of xylene and other hydrocarbons. Work on the nitration of hydrocarbons and other organic compounds in turn led to the preliminary work on the production of dye intermediates. In connection with my work on low-freezing dynamites, for example, a method was worked out and equipment designed for separating the isomeric di-nitro toluenes, and this method was later employed in making 2:4 dinitrotoluene as an intermediate in the manufacture of dyes.

Still another early assignment was an investigation of permissible explosives for use in mines, and in the early days I did all of the work myself connected with the examination of the safety properties of such permissible explosives as were then available, attending personally to the testing of these explosives by the Bureau of Mines at the Pittsburgh Testing Station, which, incidentally, had just been opened. The study of the properties of these permissible explosives from the point of view of their tendency to ignite coal dust mixed with air, or to explode mixtures of gas and air, led to the development of a wholly new series of permissible explosives, very much safer for use in gaseous mines than the earlier so-called permissible explosives.

Many interesting incidents, a few of them amusing, come to mind as I think of other phases of this early work on explosives, including the manufacture of TNT, tetryl (trinitrophenylmethyl nitramine) and picric acid, but in each and every case the story would be the same—namely, a dependence upon the products and the techniques of organic chemistry.

To the ancient industry of agriculture, the organic chemical industry has made many notable contributions. In connection with plastics, mention was made of urea, which today sells for less than one-tenth of its price in 1920. This synthetic nitrogenous chemical not only finds wide application in plastics, but also as a fertilizer ingredient. Mention should also be made of the organic mercurials which are being used so successfully for the control of various plant diseases caused by fungi, and the long-chain alkyl rhodanates for combating the ravages of sucking insects on certain agricultural crops.

In this connection mention should also be made of recent work at the Boyce Thompson Institute for Plant Research with organic compounds which modify the growth of plants. Among the more interesting of these materials are compounds such as indole butyric acid, which promote root growth even on the stems and leaves of plants to which they are applied. These so-called plant hormones, which are used in concentrations as low as 1 part in 40,000, bid fair to find wide practical application in agriculture, horticulture, and floriculture for starting cuttings of plants difficult to root.

Materials made available, either directly or indirectly, through the organic chemical industry have enriched our lives by bringing to the masses of the American people many of the good things of life which formerly were to be had only by the relatively well-to-do. Thanks to the development of synthetic textile fibers, millions of girls who work in offices and mills dress better than did the queens of a hundred years ago. In 1924 a standard type of viscose rayon sold for about $2 a pound. Today, greatly improved rayon yarns sell for approximately 50 cents a pound, and such price reductions mean large savings in clothing cost to the ultimate consumer. Moreover, the synthetic dyes used today, superior in many respects to the natural dyes used by our grandparents, are produced at a cost which adds at most only a few cents a yard to the finished fabric.

Synthetic plastics, previously referred to, have also enriched our lives by making available a wide variety of beautiful articles, including toiletware and costume jewelry, formerly made from relatively expensive materials such as ivory, jade, tortoise shell, and amber.

For our comfort, safety, and health, the organic chemical industry has provided a wide variety of products. Reference was previously made to the nonpoisonous, nonexplosive, and nonflammable fluorinated hydrocarbons widely used in domestic refrigerators and air-conditioning units. I spoke also of the new polyvinyl acetal plastics used as interliners in the safest safety glass ever made. There can be no question that many serious injuries have been averted, and many lives saved, because of safety glass.

But nowhere have organic chemicals played so vital a role as in the prevention and cure of disease. An outstanding illustration is "Salvarsan," synthesized by Ehrlich for the cure of syphilis. "Salvarsan" is now made in this country, of course, and research is credited with bringing about a 94 percent reduction in the price of this synthetic medicinal.[16]

Not since the development of "Salvarsan" has a synthetic medicinal met with such a welcome reception as sulfanilamide, or shown greater promise. Although introduced into the field of medicine only a few years ago, this coal-tar derivative has already saved the lives of thousands suffering from "blood poisoning," peritonitis, streptococcic sore throat, puerperal or childbirth fever, meningitis, and other dangerous maladies due to streptococcic infection. Although the du Pont Company does not make this product, I am proud to say that the company did prepare the sulfanilamide with which the pioneering work in this country was carried out by Dr.

[16] Chem. and Metallurg. Eng., September 1937, pt. 2, p. 546.

Perrin H. Long and his associates at the Johns Hopkins Medical School.

During the past year a related compound, sulfapyridine, has shown great promise in the treatment of pneumonia, which claims an annual toll of some 100,000 lives in the United States.

As a result of the isolation and synthesis of certain of the vitamins, various diseases due to dietary deficiencies can now be prevented or cured. Among the more important of these essential organic materials are vitamin A, a deficiency of which leads to night blindness and increased susceptibility to infection; the antiscorbutic vitamin C, now available as synthetic ascorbic acid; vitamin P–P (nicotinic acid), an insufficiency of which causes the dread pellagra; the antirachitic vitamin D, now available as irradiated 7-dehydrocholesterol; and the antiberberi vitamin B_1 (thiamin), previously referred to in connection with the effect of organic chemicals on plant growth.[17]

Similarly, the research chemist has established the constitution of, and synthesized, certain of the hormones, those little-understood secretions of the ductless glands which in some degree affect the functioning of the mind as well as regulate the chemical reactions of the body. Developments in this field offer definite promise for the cure of certain mental ills which have baffled medical science for ages.

The tremendous increases in organic chemical manufacture have made such wide and important demands for research laboratories and increased personnel to man these laboratories as to result in a great country-wide stimulation of research. From fundamental research in such sciences as chemistry, physics, biology, and pharmacology will certainly come the great developments of tomorrow, especially in the amelioration of man's health. Chemotherapy, itself as fundamentally important as the first work which flowed from Pasteur's laboratory, is nurtured by the organic chemical industry. A long list of new organic compounds awaits the attention of the research workers in pharmacology and experimental medicine. Pharmacological development will continue to be supported to an increasing degree because of the development and growth of a flourishing organic chemical manufacturing industry in the United States.

In closing I should like to leave this thought with you. Those who would attribute to our scientific development the blame for our present national and international ills take an entirely superficial view of the picture. They overlook the horrible wars that have been waged all down the years when there was no science as we know

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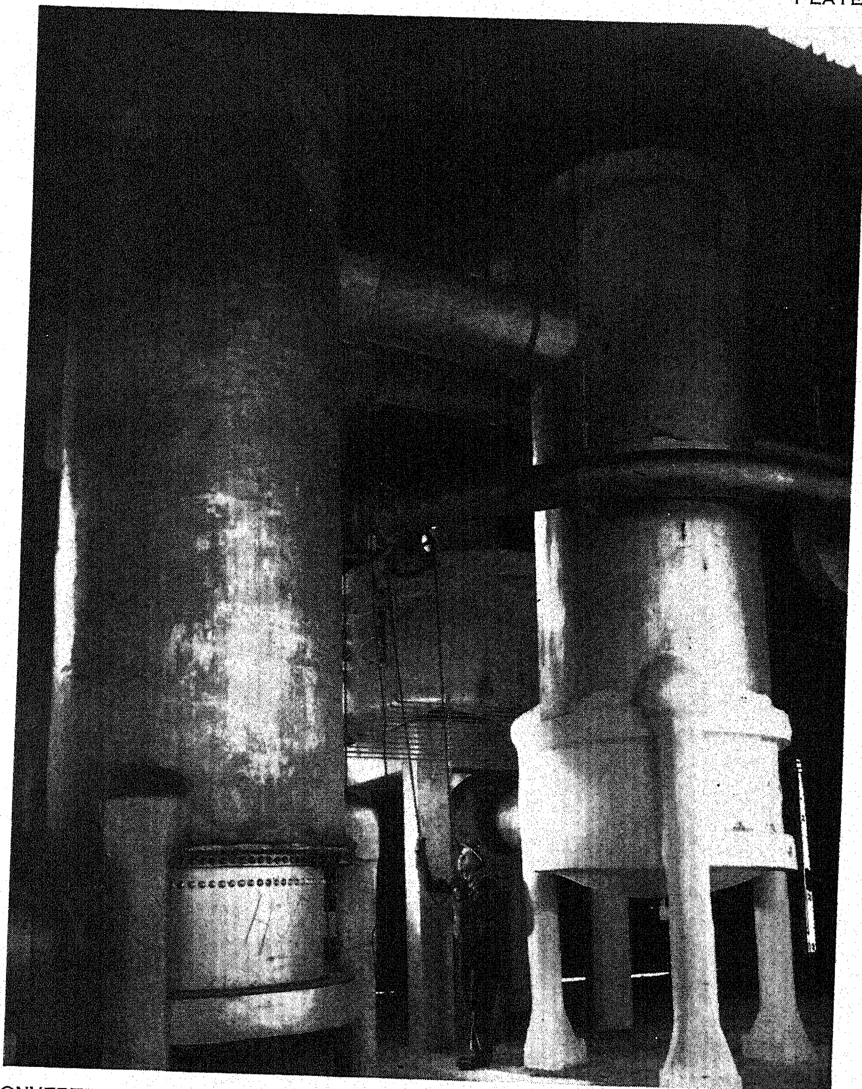
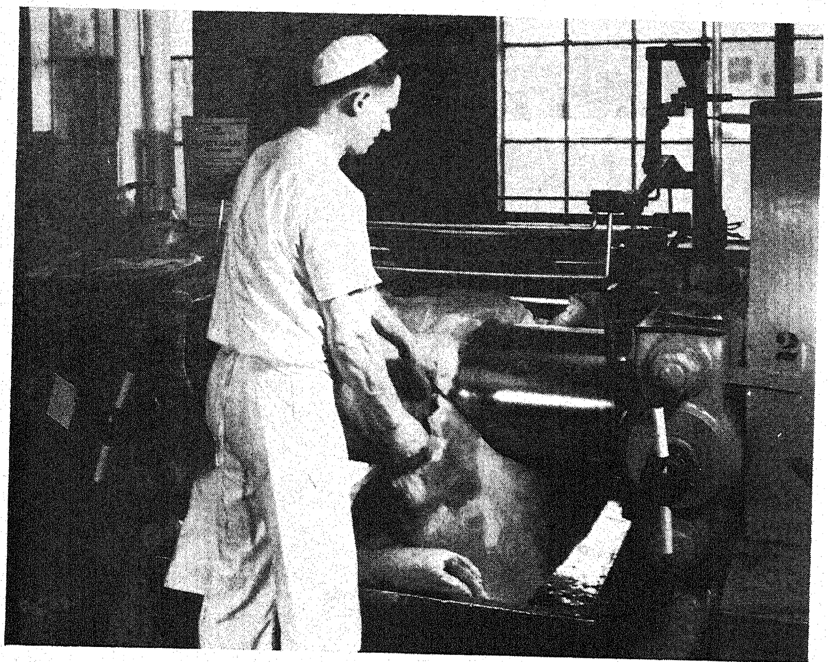
[17] Science in progress, p. 147 et seq., Yale University Press, 1939.

it today. They overlook or wilfully ignore the well-recognized fact that the lust for power by one man, or a small group of men, leads all too frequently to that great social and economic disaster called war. Until indoctrinated race antipathies and hatreds, envy, and greed for power are eliminated from human nature through spiritual regeneration, we shall have no solution of this fatal disease which afflicts humanity. Science, though it is able to confer the richest blessings upon mankind, is not able to change the heart of man and insure that the great increases in scientific knowledge will be beneficently applied. But while this is unquestionably true, I nevertheless hold that the great contribution which the development of the organic chemical industry has made to the self-sufficiency of this country is a definite contribution toward the maintenance of peace.



CONVERTERS AND HEAT TRANSFERRERS IN THE CONTACT SULPHURIC ACID PLANT OF THE GRASSELLI WORKS OF E. I. DU PONT DE NEMOURS & CO. IN PHILADELPHIA, PA.

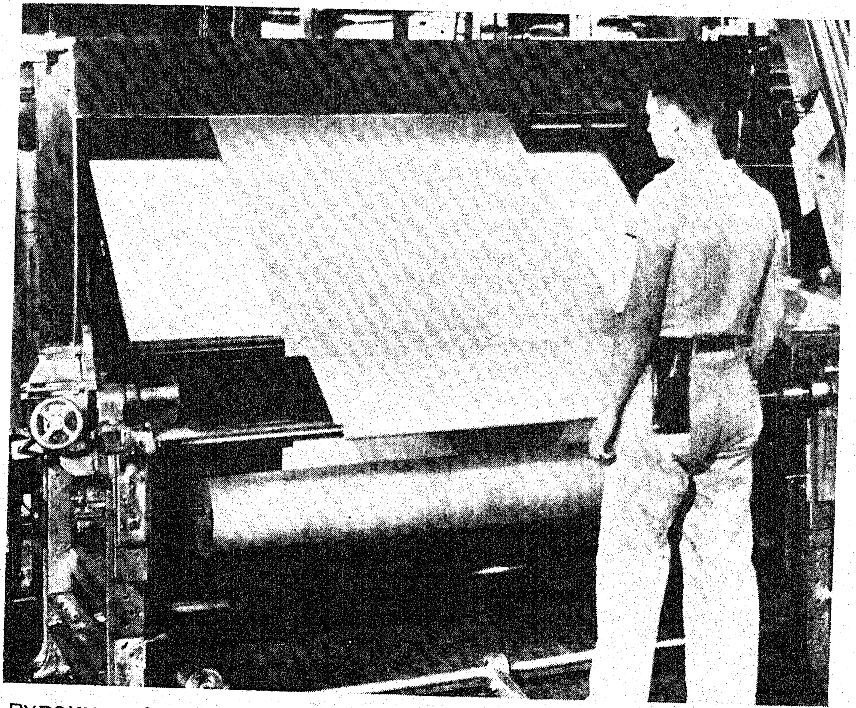
The operator is changing the valve that controls temperatures.



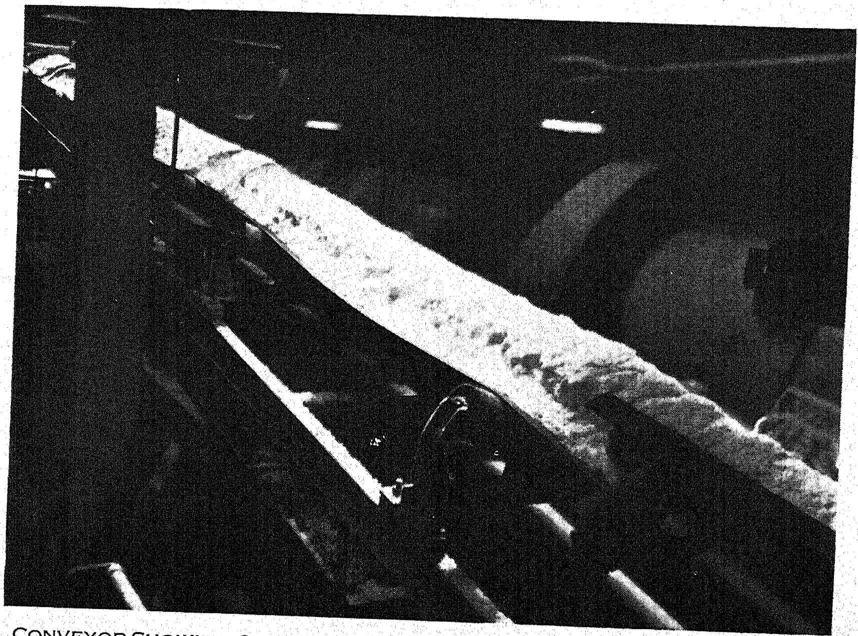
1. FROM THIS MATERIAL, "PYRALIN" CELLULOSE NITRATE PLASTIC SHEETS AND RODS ARE MADE.

The plastic is put through heavy steel rollers at the Arlington, N. J., plant of E. I. du Pont de Nemours & Co.

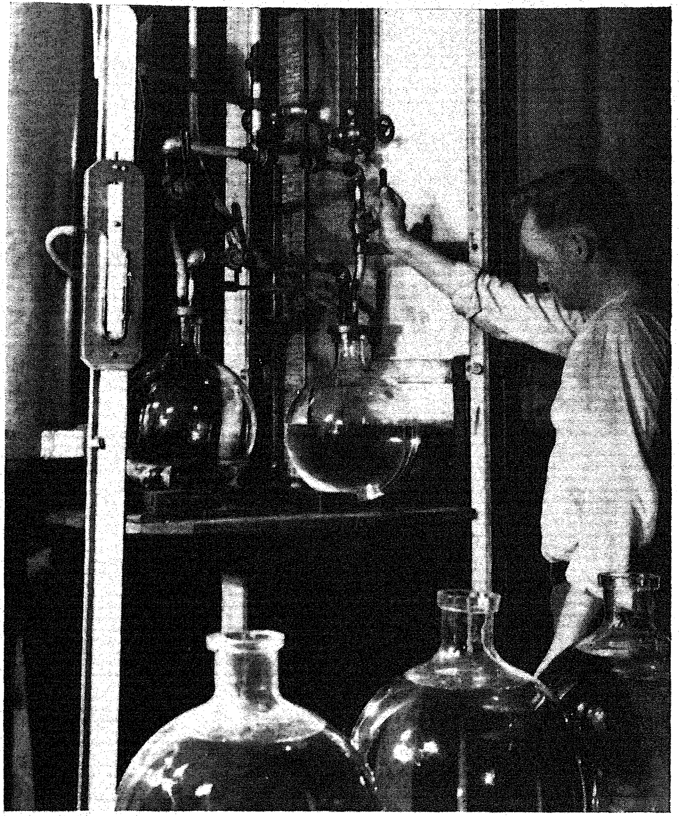
2. BATCH OF CRUDE METHYL METHACRYLATE POLYMER, THE BASE FOR "LUCITE" PLASTIC MANUFACTURED BY E. I. DU PONT DE NEMOURS & CO. AT THE COMPANY'S BELLE, W. VA., PLANT.



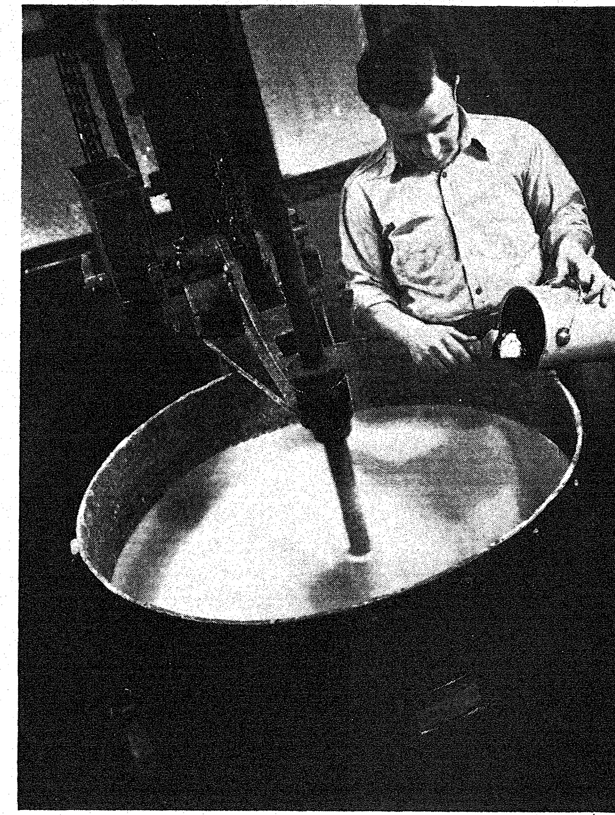
1. PYROXYLIN-COATED CLOTH UNDERGOING FINAL INSPECTION AT THE NEWBURGH, N. Y., PLANT OF E. I. DU PONT DE NEMOURS & CO.



2. CONVEYOR SHOWING CRYSTAL UREA, A PRODUCT OF THE BELLE, W. VA., PLANT OF E. I. DU PONT DE NEMOURS & CO., ON ITS WAY TO THE DRYERS.



1. AN INTERMEDIATE STEP IN MAKING SYNTHETIC LILAC PERFUME—THE DISTILLATION OF TERPINEOL—AT THE NEW BRUNSWICK, N. J., FACTORY OF E. I. DU PONT DE NEMOURS & CO.



2. PAINT-MIXING AND SHADING OPERATION ON A 50-GALLON BATCH AT THE PHILADELPHIA PLANT OF E. I. DU PONT DE NEMOURS & CO.

THE RUBBER INDUSTRY, 1839–1939 [1]

By W. A. Gibbons
United States Rubber Co., Passaic, N. J.

[With 4 plates]

The importance of Goodyear's invention is strikingly revealed by a consideration of the changes which it brought about. Before the discovery of vulcanization there was a small and struggling rubber industry. Rubber had been used by the Indians as a waterproofing material, and some rubber manufacturing was started in Europe and the United States early in the nineteenth century. While natives worked principally with latex, European and American manufacturers endeavored to use the dry rubber prepared by the natives from latex. Some experimental work had been done on methods of handling rubber. For example, it was known that rubber could be softened by heat or mechanical action and that it could be dissolved in certain solvents and spread on fabrics. It was observed that rubber so treated had reduced strength, increased tackiness, and shorter life. On this account these processes were suitable only for the manufacture of those articles which did not require a rubber of high strength or elasticity.

For products requiring a greater strength or stretch, other methods were used. The Brazilian rubber prepared by smoking latex on poles, and known as Para rubber, was relatively tough, hard, and elastic. Hancock used this rubber in the manufacture of rubber thread, bands, and rings. The process consisted of cutting the desired shape from the crude mass or biscuit. Only certain portions of the biscuits were of suitable shape for this cutting operation; the remainder was used for other purposes. To minimize this disadvantage, Hancock sent sticks of a certain size to Brazil and ordered biscuits of elongated shape, which could be cut more economically. The process of manufacture was started in Brazil and completed in Europe. Obviously a method which depended so much on obtaining the raw material in

[1] Paper read at the general meeting of the American Chemical Society in Boston September 13, 1939, in commemoration of the one hundredth anniversary of the discovery of the vulcanization of rubber. Reprinted by permission from Industrial and Engineering Chemistry, vol. 31, p. 1199, October 1939.

proper geometrical form left much to be desired. The buying of crude rubber for such applications must have attained the dignity of a fine art.

Another product which required strength and lasting qualities was the rubber overshoe. In order to obtain an article of the proper shape with sufficient toughness to give any service, it was necessary to make the shoe by applying latex to a rough last and then drying. This was done by the natives in South America, and shoes of this type were shipped in considerable quantities.

To sum up the situation: Rubber was used principally because it was flexible and waterproof; it could be plasticized and shaped, but only by impairing other important properties; if articles requiring strength and stretch were made, they were cut from selected pieces of the crude material; the products were in general of short life and low durability; they were of limited utility because they were extremely sensitive to heat and cold.

The discovery of vulcanization made it possible to use the plastic properties of rubber to bring it to the desired shape, and to convert it to a harder, tougher, and more permanent material. Rubber was the first thermosetting plastic.

Rubber, like other raw materials such as steel, glass, concrete, and paint, had dual properties important to its industrial use. In its initial stages it is soft and plastic, which permits it to be brought to the desired shape. It can then be converted to a permanent form.

Gone forever were the days of selecting pieces of crude rubber of the desired shape from which to cut out parts for the fabrication of articles of inadequate elasticity, strength, and performance. By this invention the manufacturer was liberated from a troublesome restriction as to raw material and process, and was enabled to make a product much better suited to the purpose in hand. To mankind there was made available a material so abounding in useful properties that after 100 years of constant development, its new applications are still increasing.

It is interesting to note that Goodyear's objective, although definite, was modest in comparison with the event. He had been confronted with the deterioration in properties which resulted from plasticizing and shaping rubber. His avowed purpose was to restore the original properties of the rubber:

> As early as the year 1800, wherever the properties of India rubber became known and appreciated it became a subject of much inquiry and experiment to ascertain if there was any way by which it could be dissolved, and afterward restored to its original state. This was the ultimatum sought after by great numbers who occupied themselves in experiments with it, especially those of the medical profession, as well as by the writer in all his early experiments. It was not thought of or expected (certainly not by the writer) materially to improve upon the original good qualities of the gum.

Let us consider briefly the technical aspects of Goodyear's invention. What he did was to make a mixture of 25 parts of rubber, 5 parts of sulfur, and 7 parts of white lead, and subject this mixture to heat. He found that when a piece of this mixture was heated on a stove it was changed. The result was the first piece of vulcanized rubber. Geer (3) [2] has given a vivid description of this event. He pointed out that the only "accident" was that the stove happened to be about the right temperature to produce the phenomenon of vulcanization; had it been much hotter the rubber would have been destroyed, and had it been much cooler no effect would have been noticed. Geer also pointed out that by this apparently simple operation Goodyear made four discoveries: (*a*) Sulfur is required; (*b*) another material, such as white lead, is important in accelerating the reaction; (*c*) the mixture must be heated; and (*d*) it must be heated for a definite length of time.

Sulfur, or at least gunpowder, had been used by the Indians as a dusting material to remove surface tack. Hayward had previously obtained a patent on exposing mixtures of rubber and sulfur to sunlight, with the object of drying the surface. White lead was a common pigment. Hancock and others had found that heat could be used to amalgamate pieces of scrap rubber to make a homogeneous mass. Before Goodyear's discovery, however, no one had combined these four operations.

The story of rubber from the discovery of vulcanization to the present time cannot be told as a simple sequence of orderly, related developments. For the first half of this period we have two lines of independent progress. One of these is the development and expansion of the rubber industry; the other is the scientific study of rubber. Probably for the most part the workers in one field did not know what those in the other were doing. This same situation undoubtedly existed in many industries as a result of the slowness of manufacturers to interest themselves in the application of scientific methods to their work.

COMMERCIAL DEVELOPMENT TO 1890

Shortly after the discovery of vulcanization Goodyear granted a number of licenses. The first, dated April 3, 1841, was to Nathaniel Hayward and related to "boots and shoes of felt or woolen cloth and India rubber." Hayward later transferred this license to Leverett Candee of New Haven, who together with Henry Hotchkiss and Lucius Hotchkiss had formed a partnership for the manufacture of rubber shoes, etc. This was the origin of L. Candee & Co., which

[2] Numbers in parentheses refer to list of references at end of article.

later became a part of the United States Rubber Co. In 1843 the firm of Samuel J. Lewis & Co. was organized in Naugatuck, Conn. In the same year this firm received a license from Charles Goodyear to manufacture footwear. This partnership was succeeded by the Goodyear Metallic Rubber Shoe Co., which was incorporated in Connecticut on January 9, 1845. This company likewise became a part of the United States Rubber Co. and has made rubber footwear continuously from the time of the establishment of the plant in 1843 to the present. Three of the four original subscribers were related by marriage to Charles Goodyear. It was in the Naugatuck office of one of these, William deForest, that the first vulcanized shoe was lasted.

The name "Goodyear Metallic Rubber Shoe Company" was possibly suggested by Goodyear himself, for he states (5): "Soon after the discovery of the heating or vulcanizing process, the inventor applied the term metallic gum-elastic to the improved article." In other parts of his book, Goodyear uses the term "metallic" as synonymous with vulcanization.

This early application of Goodyear's invention to overshoes is of great interest in relation to the history of the rubber industry in this country. For many years this was the most important branch of the industry. Although later other countries started the manufacture of vulcanized rubber overshoes, the American product was, and still is, regarded as the standard of quality.

As a result of Goodyear's discovery, a dying industry revived. The footwear business grew with considerable rapidity. Goodyear relates that before 1840 the total annual production of uncured rubber overshoes, made for the most part by the natives of rubber-producing countries, was around 500,000 pairs. About 1851, when he wrote his book (5), 15,000 pairs per day or approximately 5,000,000 pairs per year were manufactured in the United States under Goodyear's patent.

In 1851 Nelson Goodyear, a brother of Charles, discovered that sulfur used in large amounts would produce hard rubber.

For the next 40 years the industry itself did not make much progress in the application of chemistry to rubber. Manufacturers and inventors devoted their attention to devising and exploiting new shapes and applications of rubber, many of which were suggested by Goodyear and Hancock. Business during this period was chiefly in waterproof footwear, clothing, druggists' sundries, and certain types of mechanical goods such as hose, gaskets, washers, etc. Chemistry, as we understand the term today, was not in general use in the rubber industry. Those operations which come under the heading of rubber compounding—that is, the designing of mixtures of rubber and other ingredients to produce a satisfactory article—were on a rule-of-

thumb basis. The work was conducted by men who had grown up with the business and was carried out with the utmost secrecy.

As would be expected under such conditions, a number of fallacies developed, which flourished to a remarkable degree. For example, as late as 1892 there were definite statements in rubber handbooks that vulcanization occurs only between the melting point of sulfur and a temperature of 160° C. These statements were repeated in later editions published after the turn of the century. While these temperatures, at that time at least, may have defined the limits actually used by manufacturers, the statement itself is entirely erroneous and resulted from a failure to comprehend one of the four essentials mentioned by Geer—that is, the importance of time. Although the quantitative relation between reaction rates and temperature was known as early as 1889, these findings were not applied generally in the rubber industry until many years later.

One of the most important tasks of the rubber manufacturer during this period and even later was the choice of the proper types of crude rubber. Handbooks on rubber devoted much space to a discussion of various botanical species which produce rubber and to the types of rubber obtained from them. Crude rubber produced in those days was prepared by the natives of South and Central America, Africa, and the East Indies. Primitive methods were used. The best rubber, known as fine Para, was obtained from Brazil. This was produced by dipping a stick in latex and coagulating the latex by holding the stick over a fire of urucuri nuts. The smoke of this fire contained certain acidic materials, such as acetic acid and phenols, which coagulated the latex. The operation of dipping and drying was repeated until a substantial mass, called a "biscuit," was obtained. For many years this product was a standard of quality. It owed its excellence both to the particular tree, *Hevea brasiliensis*, from which the latex was obtained, and also to the method of preparation; although crude from the standpoint of operating efficiency, this method was more satisfactory than those used elsewhere. In other localities, for example, latex was allowed to dry on the surface of the tree, and the film of rubber, together with much adhering foreign matter, was peeled off. In still other cases natives smeared the rubber on their bodies and allowed it to dry.

The rubbers prepared by these diverse methods differed greatly in properties from one type to another. Also, there was great variation in shipments of supposedly the same grade of raw material. The prices of these different grades varied both on absolute and relative bases, and a vast amount of experience and skill was required in order to make the best use, from the standpoint of both cost and quality, of available raw materials.

PLANTATION RUBBER

In 1876 an event occurred which was destined to create a profound change in the production of rubber. An Englishman, Henry Wickham, succeeded in transporting a supply of seeds of the Hevea tree from Brazil to England. Wickham had previously devoted several years to the study of these trees in their native jungles, and had selected and carefully picked seeds from the best type of tree. The seeds were planted in Kew Gardens, and the seedlings from them were transplanted in Ceylon.

In spite of what appeared to be a good start, plantation rubber developed slowly. In 1909, 3,600 tons of plantation rubber and 66,000 tons of wild rubber were produced. By 1913–14 the production of plantation rubber equaled that of wild rubber. At present practically all the world's supply of rubber comes from the plantations, and the total potential world production has grown to around 1,500,000 tons per year.

Great improvements have been made in the art of growing rubber. The early books on the plantation industry record yields of around 300 pounds per acre. A great deal of work was carried out in the East on the application of genetics to rubber planting; as a result the yield has been greatly increased. At present the average annual yield per acre on the European and American owned plantations is 450 pounds per year. High yielding areas have produced as much as 2,000 pounds per year.

Although the trees planted in the East are of Brazilian origin, the type of crude rubber produced on the eastern estates is quite different from the Para rubber of Brazil. The plantation rubber in practically all cases is made by coagulating latex by the addition of an acid, such as acetic or formic, and then forming the coagulum into a sheet which is washed and dried. In many cases the sheets are hung in a smokehouse, and the product is known as smoked sheet.

INVENTION OF THE PNEUMATIC TIRE

Another event of far-reaching importance was the invention of the pneumatic tire, patented by Dunlop in 1888. Dunlop's first tire was a rubber tube, with means for inflation, held to the rims of a tricycle by tape. The introduction of the bicycle gave an impetus to the development of tires, which was still further stimulated by the invention of the automobile.

SCIENTIFIC WORK TO 1890

Let us now consider the scientific work which was done between 1839 and 1890. Goodyear's discovery was made at a time when chemistry was in its infancy. Although a few of the basic chemical

laws, such as those of Avogadro and Gay-Lussac, and the laws of definite and multiple proportions were known, present-day organic chemistry did not exist. At that time substances derived from natural living sources were generally assumed to be fundamentally different from those of inanimate origin.

Previous workers in chemistry had confined their attention chiefly to those forms of matter which possessed definite critical criteria—in other words, solids, liquids, or gases. The interrelationship of pressure, volume, temperature, and change in weight as a result of chemical reaction, were about the only criteria for studying chemical reactions.

Faraday (2) was the first to publish the ultimate analysis of rubber, and the carbon-hydrogen ratio which he determined is used today. At the time Faraday made his analysis, there was considerable activity in studying various organic materials, all of natural origin. Dry distillation of organic substances or mixtures had come into use as an experimental method for obtaining information regarding the constitution of complex substances, and rubber was one of the natural substances which was studied in this way.

Himley (7) in 1838 obtained two hydrocarbons from rubber; one of them he called "Faradayn," and it may have been isoprene.

Williams (22) in 1860 definitely identified isoprene as one of the constituents resulting from the dry distillation of rubber and showed that it had the same hydrogen-carbon ratio as rubber.

The present accepted structural formula for isoprene was established by Tilden (18) in 1884.

Bouchardat (1) in 1875 and Tilden (19) in 1892 showed that isoprene or its hydrochloride could be polymerized under certain conditions to give a rubberlike substance; furthermore, he showed that this rubberlike substance on dry distillation gave the same volatile hydrocarbon as rubber.

Aside from their historical interest these researches are important because they form the basis of our present knowledge of the manner in which rubber, or at least rubberlike substances, can be obtained from synthetic materials—that is, by the polymerization of compounds containing conjugated double bonds.

Another scientific foundation stone of great importance to the later development of theories of vulcanization was the work of Gladstone and Hibbert (4) who in 1888 measured the refractive index of rubber and concluded that it was unsaturated. This was confirmed by their observation that rubber under the proper conditions forms an addition compound with bromine.

The scientific studies of rubber were for the most part independent of the industrial development during this period. Although

we have no record of the first employment of chemists in the rubber industry or why they were employed, the conventional guess would be that it was in connection with the application of analytical methods either to raw materials or to the finished products, including competitors' products. An interesting side light is furnished in a note by Weber (20) in 1903 entitled "The Importance of Chemistry in the Rubber Industry." Weber says:

Slowly but surely are silenced those once so numerous voices which assured us positively a few years ago that the efforts of the chemists to solve the chemical side of rubber manufacturing are commendable, but fail of accomplishment, and in any case would be superfluous. The possibility of a secondary usefulness of chemistry in carrying out analyses of raw materials and occasionally of a sample of rubber, however, was admitted, with the emphatic statement that herewith the importance of chemical methods had reached an end as far as rubber was concerned. The only "catch" in these statements, well meant without doubt, was that they were made by nonchemists. I recall quite similar lamentations (Jeremiade) which greeted the arrival of chemistry in the leather and paper manufacture, and also that even in the iron and steel industry the chemist had been looked upon for a long time as a kind of idealistically inclined spendthrift, and that it took the chemists a long time to attain their present importance.

In 1892 Henriques (6) published articles on the analysis of rubber.

In 1890 C. O. Weber started his career in the rubber industry. Weber had studied under Bunsen at Heidelberg and later at the universities of Zurich and Freiburg. He had previously been interested in coal tar and dyestuffs. When Weber entered the industry, little or nothing was known of the chemistry of rubber manufacture. The phenomenon of vulcanization, of which the industry had made such enormous use for over 50 years, had received practically no attention even from the empirical point of view. Rubber manufacturers were still arguing as to what was meant by "perfect cure." Little or nothing was known regarding the relation of time and temperature to the degree of vulcanization. Although it was recognized that sulfur did something important to the rubber, until Weber's time there was no recognition of any quantitative relation.

Weber investigated the relation between the time and temperature at which rubber was vulcanized, and the amount of combined sulfur in the resulting product. The percentage of combined sulfur based on the rubber, he called the "degree" or "coefficient of vulcanization." Thus for the first time a clear conception of the quantitative nature of the process and a practical method of measuring it were available. Although this method has its faults, it has been of enormous use to the rubber industry in controlling and developing new products, and is in general use at the present time.

From this time on there was a rapidly increasing interest on the part of the rubber industry in the application of scientific information

and methods. Part of this was due, no doubt, to the contemporary development of improved technique in other industries, and part to the increasing demands made on the rubber industry to manufacture better products and to adapt rubber to new uses. Textbooks and handbooks on various subjects relating to rubber made their appearance, and in general the technical part of the industry, at least, may be said to have developed the art of self-expression. It was found possible for rubber technologists to disseminate technical information regarding the methods of testing their products and regarding the general principles of manufacture without injuring the organizations by whom they were engaged.

The fruits of this happy union of science and the rubber industry have been numerous. There was increased activity in the study of rubber both in the universities and in the industry; the results have not only given us a greater insight into the structure of rubber and the mechanism of vulcanization, but have also led to practical improvements in the manufacture of rubber products which have been of outstanding importance to the world. In the remainder of this paper we shall discuss these various developments by subjects rather than chronologically.

RUBBER STRUCTURE

Harries, in his researches beginning in 1904, investigated the ozonides and other derivatives of rubber, and his results are the most convincing evidence we have for the basic structural unit of the rubber hydrocarbon. The theories of Harries and other workers of this period are based almost entirely on chemical reactions and particularly on ozonization studies, and did not attempt to explain the long-range extensibility and other important properties.

According to Staudinger and Bondy (17), who used viscosity methods, the molecular weight varies from 180,000 for Hevea crepe, down to 11,700 for rubber oxidized with air. Determinations of molecular weight by osmotic methods show values around 129,000 (14). Kraemer and Lansing (11), using both ultracentrifugal and viscosity methods, found a molecular weight of over 400,000. In spite of the quantitative discrepancy between molecular weight determinations by different investigators, we are at least justified in concluding that the value is extremely high. This high molecular weight of rubber is important because, according to modern theory, many of the unusual properties of rubber are accounted for by its high molecular weight. A number of theories have been proposed during the past few years based on space models contrived in an attempt to explain the high extensibility and elasticity of rubber. The most widely accepted theory was developed in detail by Kuhn and others (12). According to them, rubber consisted of long threadlike mole-

cules, and the elasticity of the rubber is explained by the thermal motions of the molecules. When the rubber is relaxed, the thermal agitation of these long threadlike molecules causes them to assume a disordered, kinked condition. Small van der Waals forces permit long-range extensibility. When the rubber is stretched, the molecules are brought into alinement in the direction of the stress, and the thermal agitation now makes itself evident by a tendency of the rubber to retract and produce again a disordered, rather than an orderly arrangement of the molecules. In other words, the entropy of the rubber tends toward a maximum. It is further assumed that when the rubber is stretched, partial crystallization occurs. This is supported by the observation of Katz (9) in 1927 that stretched rubber gives a definite X-ray diagram. This partial crystallization results in an evolution of heat, and it is due to this effect that the temperature coefficient of the stretching and relaxation is greater than would be predicted on the assumption that no partial crystallization took place. This explains the reversible Joule effect.

THEORY OF VULCANIZATION

A satisfactory theory of the structure of rubber should not only account for the elastic properties of rubber in the unvulcanized condition, but should also explain changes in the physical properties of rubber produced by vulcanization. These changes were mentioned early in this paper in connection with the work of Goodyear and Hancock. From a scientific point of view the most important effects of vulcanization are a great increase in the temperature range over which rubber exhibits elasticity, a lower permanent set or plastic flow at a given temperature, and a marked decrease in swelling in organic liquids.

There has been a certain parallelism between various vulcanization theories and contemporary chemical thought. Thus in 1851, Brande, writing on the organic chemistry of rubber, stated that he could remove all of the sulfur after vulcanization, and that the rubber remained vulcanized. He therefore assumed that the vulcanizate was an allotropic form of rubber. Some of the later theorists regarded vulcanized rubber as an indefinite combination of alloys of rubber and sulfur.

Weber concluded that the process of vulcanization involves the formation of a series of addition products of hydrocarbon and sulfur; that as the sulfur content of these compounds increases there is a decrease in distensibility and an increase in rigidity; and that the term of this series—i. e., the degree of vulcanization produced—is in every case only a function of temperature, time, and proportion of sulfur present.

Vulcanization was regarded as an adsorption phenomenon by Ostwald.

Ostromislensky proposed a theory which was in part a combination of the foregoing. He assumed that there was only one chemical reaction—i. e., the formation of the hydrocarbon saturated by the addition of sulfur; and that this compound, which would be produced only in small quantity in the ordinary soft-rubber formula, was adsorbed by the remainder of the rubber which had been unaffected by the sulfur.

A satisfactory theory of vulcanization should account for the change in physical properties as well as for the chemical change. The most commonly accepted view at present appears to be that the long-chain molecules, of which the rubber hydrocarbon is assumed to consist, are bound together by cross links as a result of vulcanization. The exact nature of these cross links has not yet been definitely established.

The development of theories to account for the structure of rubber and the phenomenon of vulcanization are of undoubted importance in expanding our knowledge of rubber, although they have not yet resulted in any important practical application in the manufacture of rubber products.

ACCELERATORS

In the discussion of Goodyear's work, mention was made of the fact that in his first experiment he used lead carbonate in addition to sulfur and rubber. Goodyear and those who made the first use of his invention recognized that lead carbonate and other lead compounds materially assisted in the vulcanization process by shortening the time. It was later found that certain other inorganic materials, such as lime, magnesium oxide, and antimony sulfide, produced a similar effect. These materials were in general use by the rubber industry until the early part of this century.

In 1906 Oenslager introduced the use of aniline and aniline derivatives as accelerators. He found that these compounds were much more effective than the inorganic accelerators. This permitted the use of smaller quantities and a greater reduction in time and temperature of cure. This work was kept secret for a number of years. In 1914 the German patent of Hofmann and Gottlob (8) was issued. This was apparently the first published disclosure of organic accelerators, and discussed the use of a number of free organic bases and of their carbon disulfide addition products. From this time on, there has been great activity in the field of organic accelerators.

A large number of patents have issued on this subject and many excellent scientific articles have been published. Here, however, only the most important developments will be mentioned. Aniline was

employed generally for a number of years. Thiocarbanilide and hexamethylenetetramine then came into use.

The aldehyde-amines developed by Cadwell and others were an important addition to the rapidly growing list of accelerators. Guanidines were also discovered to be quite effective and have had wide usage. Mercaptobenzothiazole was reported to be an accelerator by Bedford and Sebrell and also by Bruni in 1921. It has been employed in many classes of rubber goods. It was found that zinc oxide increased the effectiveness of many accelerators. One of the most spectacular discoveries, of which little commercial use has been made, was the observation that in the presence of zinc oxide and certain chemicals the rate of vulcanization is accelerated and vulcanization will occur in a reasonable time at room temperature.

The inorganic accelerators such as litharge, and the early organic accelerators such as an aniline, were used principally to accomplish more rapid vulcanization. This permitted the manufacturer to realize considerable economies in the output of his plant equipment. In order to secure a satisfactory state of cure, however, it was necessary in many cases to use an excess of sulfur, with the result that after the vulcanization was completed a substantial amount of uncombined sulfur remained. Some of this appeared on the surface as a powdery deposit. This was known as bloom and was a familiar characteristic of rubber goods made during the period. Certain difficulties in the control of the product were also introduced since the amount of sulfur combined with the rubber was in direct relation to the time of heating, up to the point where all the sulfur was combined. The common practice of the day required from 7 to 10 percent of sulfur in the mixture in order to secure from 2 to 5 percent of sulfur combined after vulcanization. It is evident, then, that unless the temperature conditions were carefully controlled, one might easily make a product with more than the desired amount of combined sulfur.

With the introduction of modern organic accelerators this difficulty was largely corrected. It is now possible to vulcanize rubber in such a way that all, or practically all, of the sulfur is combined. If the manufacturer desires to have 3 percent of sulfur combined with his rubber, approximately that amount is used in the formula. The modern accelerator also permits the manufacture of goods of any desired color without the later development of an unsightly bloom of free sulfur. Further, it permits the vulcanization of rubber goods of any color in an atmosphere of heated air. Before the introduction of organic accelerators the only rubber goods which were vulcanized satisfactorily in hot air were those accelerated with litharge or other lead compounds. During this operation a certain

amount of lead sulfide was formed; accordingly, the only colors which could be produced were black or dark brown.

The long heating practices and other conditions necessary to vulcanize rubber in the earlier period imposed certain other serious limitations on the product. There was a great variability in responsiveness of crude rubber to vulcanization. Modern accelerators have made a great improvement in these conditions and have also increased the strength, elastic properties, and durability of rubber.

The practical effect is that an immense amount of money has been saved to the rubber industry and to the public in increased output of plants; and what is probably more important, the usefulness of rubber has been greatly expanded. Old products have been improved and made suitable to modern working conditions, and many new products have been produced which would hardly have been possible with the older methods.

Although an enormous advance has been made in the technology of accelerators, we are still without a fully satisfactory theory to explain their action. Possibly there is no one theory which could adequately explain their action, because so many different classes of chemicals have accelerating power. Certain chemicals, such as the thiuram and xanthic disulfides, are capable of vulcanizing rubber without the inclusion of any free sulfur in the formula. Vulcanization in such cases takes place at a rapid rate. The current opinion is that the accelerator forms an intermediate compound with the free sulfur and that the sulfur is then split off in active form, but exact information about the way various accelerators do this is lacking.

NONRUBBER INGREDIENTS

From the earliest time it was observed that commercial rubber contained substances other than the so-called rubber hydrocarbons. Some of these which were soluble in acetone were called "resins." It was also found that there was a great difference in the susceptibility of various types of crude rubber to vulcanizing conditions. The reason was for many years a mystery. Whitby, Bedford, and others found that this so-called acetone extract or resin ingredient was of great importance in the vulcanization process, particularly under the conditions in use before the discovery of organic accelerators. Whitby showed that in Hevea rubber, such as fine Para or plantation rubber, the acetone extract consists largely of fatty acids. These fatty acids have an important role in reacting with the basic mineral materials such as lead oxide and zinc oxide, and if these fatty acids are not present in sufficient amount, vulcanization is seriously impaired. It was found that this deficiency could be made up by the addition of fatty acid such as stearic, and that with

certain of the newer accelerators it was highly desirable to add additional fatty acid. This discovery is of great practical importance, as it tends to eradicate one of the troublesome variables in the supply of crude rubber—that is, the variability in curing rate.

COMPOUNDING AND REINFORCEMENT

The earliest workers were accustomed to blend rubber with other ingredients. Although these materials were added for various reasons, in many cases the purpose was admittedly to cheapen the mixture. Rubber at that time was high in price, and neither the manufacturer nor the consumer had developed tests and specifications for quality. Furthermore, the crude rubber obtained from the Tropics was in many cases of low quality and, either through ignorance or desire, was mixed with adulterants. According to an early handbook (15), Rousseau proposed the following definition: "The manufacture of India rubber is the art of incorporating with it cheap substances without too far diminishing its particular properties." While this criticism may have been harsh in some cases, it was probably justified in many others.

As it became necessary to develop rubber compounds to withstand severe operating conditions, rubber manufacturers became interested in the effect of various so-called fillers on such properties as abrasion resistance and resistance to stretch. It was found that if used in sufficient amount, zinc oxide had the property of actually increasing the tensile strength of a rubber compound, although it was not recognized at that time that part of this effect was due to a favorable chemical action on the vulcanization phenomenon. With the increasing importance of the automobile tire, rubber manufacturers adopted zinc oxide as the standard filling ingredient for tire-tread compounds. For many years white tires were the rule, and the best tires were those which owed their whiteness to a sizable portion of zinc oxide. Those materials which, when added to rubber increased its tensile strength and elastic modulus, were termed "reinforcing agents," in distinction to those substances which acted merely as inert fillers.

The history of the modern method of compounding and reinforcement, therefore, dates from the first discovery that if certain substances, such as zinc oxide, are used in sufficient quantities, they will produce a reinforcing effect; the quantities to produce this effect are greatly in excess of those used when color is the only consideration.

A few years before the World War it was observed that carbon black showed reinforcing effects in rubber. While some pneumatic tires using carbon-black treads were made in this country before the war, the white tread continued in general use for several years.

However, the shortage of zinc during the war period caused manufacturers to employ carbon black in increasing amounts. This change, which was probably in many cases a matter of necessity rather than choice, was destined to have a far-reaching effect on the performance of rubber products, particularly tires. Carbon black had been known and used for many years by the rubber industry but principally as a coloring agent, and it was therefore employed in relatively small amounts. There was little or no publication of scientific data on carbon-black compounds during the war, but a number of articles have appeared since that time, beginning with the work of Wiegand (21). These studies have demonstrated the remarkable properties of carbon black in rubber.

Most of these properties are favorable. In addition to increased tensile and higher modulus, carbon-black compounds are tough and give a higher resistance to abrasion.

A great deal of work has been done in an endeavor to explain the properties of carbon-black compounds. Carbon black possesses a number of properties which differentiate it from other materials in powder form, and there has been a tendency to hold all of these differences responsible for the peculiar properties of carbon-black-rubber mixtures. Of these various factors, rubber technologists are in general agreement that fine particle size is the most important. This is supported by the observation that fillers of entirely different chemical composition have been made of varying particle size and that they have shown a tendency to give increased reinforcement as the particle size diminishes.

ANTIOXIDANTS AND IMPROVEMENT IN AGING RESISTANCE

From the earliest time it was noted that rubber and its products deteriorated. Most of us today have little idea how serious this problem was to the rubber industry 100 years ago. The extreme variability of the wild rubber and the unsatisfactory methods used to produce it at that time have been mentioned. In addition, for most articles it was necessary to reduce the rubber to a softened condition in order to form the article. One way of doing this was by the use of a mill and calender. Another method was to disperse the rubber in a solvent and then spread the resultant dough on fabric. This was the method used by Mackintosh, whose name was applied to the waterproof coats made by this process.

There have been several cases in the history of rubber where good fortune seemed to attend the inventor and the manufacturer. Mackintosh, however, was not entirely fortunate. He selected turpentine as his solvent, which, according to present knowledge, was about as poor a choice as could have been made. The tendency of turpentine

to oxidize spontaneously, which made it useful in paint, undoubtedly contributed a great deal to the difficulty which was experienced by the proofing industry in those days. It was a common event for rubber compounds to turn to a sticky, gummy condition and later to become brittle and worthless. Mackintosh, Hancock, and Goodyear all had a great deal of trouble on this account. Goodyear hoped to restore rubber to its original condition by vulcanizing, and he was surprised when the improvement went beyond that. Although vulcanization did greatly improve matters, rubber goods were a source of trouble both to the manufacturer and to the user because of their highly variable life.

As the knowledge of the structure and properties of organic chemicals developed, the reason for the rapid deterioration of rubber became more evident. This is summed up as follows by Semon (16):

> From a purely chemical viewpoint, it is not difficult to understand why rubber should oxidize in air, for both raw and vulcanized rubber show about 85 percent more unsaturation than linseed oil. The iodine number of linseed oil is from 175 to 200, whereas that of raw or vulcanized rubber is from 350 to 372. The surprising fact, therefore, is not that rubber deteriorates, but that it is so stable.

It was recognized many years ago that the oxygen of the air played an important role in the deterioration of rubber. It was also found that deteriorated rubber always contains combined oxygen. Later accurate measurements showed that a relatively small amount of oxygen, combined in this way with the rubber, produced a profound effect on the properties of the product.

The theoretical aspects of the oxidation of rubber were studied by a number of scientists, including Moureu and Dufraisse, Kirchhof, and Ostwald. Important contributions were also made by workers in industry, particularly with respect to the effects of certain impurities, such as copper and manganese, which greatly accelerate the deterioration of rubber by oxygen. The phenomenon of oxygen deterioration has received more attention at the hands of scientists than the phenomenon of vulcanization.

According to current theories, rubber is depolymerized when it oxidizes. This is borne out by the fact that the viscosity of a solution of unvulcanized rubber is reduced by oxidation. Vulcanized rubber oxidizes more readily than unvulcanized rubber. Although the mechanism of the oxidation reaction is still being investigated, it is generally believed to be autocatalytic.

While a number of substances had previously been proposed as preventives of oxidation, the first materials put to large-scale use were the aldehyde-amines. Aldol-α-naphthylamine, proposed by Winklemann and Gray, and acetaldehyde-aniline, proposed by Cadwell, are the first representatives. The aldehyde-amines have already been

mentioned as an important class of accelerators. It was found that they can be prepared in such a way as to have nonaccelerating properties and yet give substantial improvement in resistance to aging.

The original purpose of antioxidants was to prolong what might be called the ordinary life of rubber goods—that is, to make them less likely to soften or become brittle with time. Later, however, it was found that they conferred other beneficial properties on certain types of rubber compounds. Resistance to abrasion and to cracking on repeated bending, known as flex cracking, were also improved.

We have discussed the aspects of that department of rubber technology commonly known as rubber compounding. The work relating to the acceleration of vulcanization was initiated in order to reduce the time and therefore the cost of vulcanizing. We have seen that the use of compounding materials originated from motives still more mercenary—namely, the desire to make a pound of rubber go farther; but as a result of these two developments and from the work on retarding deterioration, enormous sums have been saved to the consumer. This is not because the investigators merely achieved their original objectives, but because in attacking problems which were worth while in themselves and which were fundamental to the industry, they obtained unexpected and unlooked-for quality advantages far in excess of the original goals toward which they worked.

INDUSTRIAL USE OF LATEX

The Indians manufactured ponchos and crude forms of footwear directly from latex, but there was no industrial application of latex in the rubber manufacturing countries until after the World War. The plantation industry had meanwhile developed to the point where it was feasible to ship rubber in this form on a large scale. By the direct use of latex, an improvement has been made in the manufacture of certain types of rubber goods. Also, industries which have heretofore been unable to use rubber now find it feasible to incorporate it in the form of latex in certain products.

In the manufacture of rubber goods, latex is frequently used in place of organic dispersions of rubber for the manufacture of dipped goods, such as gloves, and of spread-sheet products. It is also employed for treating tire cords and other textiles used in the manufacture of rubber goods.

One of the most interesting applications is the direct manufacture of rubber thread from latex. We have already referred to the methods used by Hancock, whereby threads were cut direct from biscuits of fine Para. After the discovery of vulcanization this method was superseded by one in which the rubber, sulfur, and other

ingredients were mixed together, and the product sheeted on a calender, vulcanized, and then cut mechanically to form threads of rectangular cross section. In the latex process the operation is continuous, the latex compound being introduced at one end of the machine and the dried and vulcanized product being delivered from the other.

Latex provides a highly satisfactory medium for the introduction of rubber in varying amounts into other materials or products. It is now used in the manufacture of paper. In one process the latex is introduced in the beater. In another process a specially prepared paper is passed through a bath of latex. Latex is also used for the manufacture of pile fabrics and a number of other products where it is desirable to utilize a rubber dispersion of high concentration and low viscosity, and where a rubber which is tough and of high quality is required.

The shipment of rubber in the form of latex has grown rapidly. In 1923, 2,300 tons were shipped; in 1938, 22,950 tons. Although this is small compared with the total, it is equal to the world's production of rubber in 1890.

SYNTHETIC RUBBERLIKE PLASTICS

By the middle of the nineteenth century, owing to the development of organic chemistry, there was great activity in synthesizing from simpler materials those organic compounds which occur in nature. As would be expected, rubber with its unique properties excited the interest of a number of organic chemists, and a great deal of work has been done in an endeavor to develop a practical synthesis. In the strict sense of the term, no one has made synthetic rubber; that is, no one has prepared a product identical in physical and chemical properties with the natural product. However, a number of new products have been produced which are sufficiently similar to rubber to permit their use in place of rubber in certain products, and which are sufficiently superior in certain respects to make such use practical in spite of higher cost. These materials may conveniently be classified into two groups: Butadienoid polymers—that is, those made by the polymerization of butadiene and similar compounds; and nonbutadienoid polymers.

Butadienoid Polymers: These resemble rubber in that they are unsaturated and vulcanizable. They are probably fairly close to natural rubber in structure.

Isoprene.—Bouchardat first polymerized isoprene. Tilden is commonly regarded as the first to show a method of synthesis because he discovered that isoprene could be obtained from turpentine, an independent source of raw material. This method is of no com-

mercial interest on account of high cost. Although other sources of isoprene were proposed and patented, no commercial use is being made of this synthesis.

Butadiene and Dimethylbutadiene.—These two homologs of isoprene have also been investigated. Lebedev in 1910 (13) reported that a rubberlike polymer is produced by heating a butadiene. Kondakov in 1900 (10) reported that when 2,3-butadiene was heated with caustic potash he obtained a rubberlike plastic material.

Apparently no attempt was made to commercialize these two discoveries until the shortage of rubber in Germany during the World War induced German chemists to investigate possible substitutes for natural rubber. They concentrated on the synthesis from dimethylbutadiene, probably because this hydrocarbon was more easily made than butadiene. The rubber produced by the polymerization of dimethylbutadiene was known as methyl rubber. It was used particularly for hard rubber, and by the spring of 1918 over 30 tons per month were utilized for this purpose.

Soft products produced from methyl rubber had low elasticity, and the tires and tubes made from it were short-lived.

After the war, interest in synthetic rubber lapsed for several years but was renewed about 1926, probably on account of the rapid increase in the price of natural rubber about that time. Since 1926 most of the activity appears to have been on the butadiene type of rubber. The polymers of butadiene and vulcanizates made from them are much closer to natural rubber in properties than those of dimethylbutadiene. In addition, better products were made by cross-polymerizing butadiene with other compounds. At present, substantial quantities of these synthetic rubbers, known as Buna S and Buna N, are produced and used in Germany in place of natural rubber.

Chlorobutadiene.—Polymerized chlorobutadiene, known as neoprene, was the first synthetic rubber used commercially in this country. Unlike the earlier members of this group, neoprene is not a polymerized hydrocarbon but is the polymer of β-chlorobutadiene. For purposes of rough comparison, β-chlorobutadiene may be regarded as isoprene with a chlorine atom in place of the methyl group. The polymerized product is characterized by a much higher resistance to oils and other organic solvents than natural rubber and a much higher resistance to cracking from light and ozone; it is used for the manufacture of products where these enhanced properties are sufficiently important to offset the increased cost.

The vulcanized products of butadiene and chlorobutadiene are essentially rubbery in character, and possess good strength, good stretch, and the ability to recover their original form when the stress is removed.

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Since we are today celebrating the centenary of the great invention of vulcanization, let us note that this principle, with some modifications, applies to these newest achievements of the chemists, although as far as we know, Goodyear himself never foresaw the possibility of vulcanizing any material other than rubber.

NONBUTADIENOID SYNTHETICS: Several products in this group are in commercial use. Although these materials do not have a close resemblance chemically to rubber, their physical properties permit them to be handled on rubber machinery. The principal products in this group are:

Polyvinyl compounds.—Plasticized polyvinyl chloride, known as Koroseal, is used for products where resistance to corrosive chemicals is important. Plasticized polyvinyl alcohol is employed for certain applications where high resistance to oils and other solvents is required.

Reaction products of ethylene dichloride and similar compounds with sodium polysulfide, known as Thiokol, are rubberlike bodies characterized by good resistance to oil.

Polyisobutene, known as Vistanex, is a rubbery polymer which is used in electrical and other applications.

It is not possible at this time to make any prediction as to the extent to which these or any other synthetic materials will replace natural rubber. Synthetics cost more than rubber and, although they are superior to rubber in some respects, they are inferior in others. Assuming that the supply of natural rubber is not interfered with by war or any other circumstance, the question as to whether or not any substantial amount will be replaced by synthetic materials depends on the price at which synthetics can be made, and on how good the product is, both from the standpoint of ease of processing and the quality of the finished article.

It is quite likely, however, that as new fields for rubberlike products are developed, the synthetic materials will be used in increasing amounts, since they are suited to applications for which natural rubber is unsuited.

THE MODERN TIRE

The modern automobile tire is a concrete example of most of the important technological advances which we have been discussing. Those of us who can recall the goggles and linen duster era of the motor car will also undoubtedly have vivid recollections of the troubles of the motorist of that day. On long trips it was customary to carry several spare tires on account of frequent blowouts and punctures. It is now customary in most cases to carry only one spare tire, and that is seldom used. In addition to these difficulties the tires wore out so rapidly that tire cost was one of the important items of expense in car operation. During the first decade of the twentieth

century a life of 5,000 miles would have been regarded as high. The tire of today is an enormous improvement in every respect. Many of the improvements have resulted from the practical application of developments which have been discussed in this paper.

The modern tread is several hundred percent better in wear than the old tread. An exact comparison is difficult to make because meanwhile the increased speed of cars and increased efficiency of brakes have made the task of the tread still more difficult. This superiority is a result of the application of chemistry and engineering. Tread rubber has been vastly improved by the proper use of carbon black, accelerators, and antioxidants. In addition to wear, the modern tread is much safer from the standpoint of skidding than the older tread would have been. I put it this way because the earlier cars, operating with low acceleration and inefficient brakes, did not demand so much in the way of skid resistance as the modern car. Proper engineering of the tread design has been a major factor in the improvement of treads in this respect.

In addition to the improvements in tread wear and safety, the modern tread has to cope with conditions which require the utmost in engineering. Freedom from noise, stability, riding comfort, easy steering, low wind drift, and freedom from tramp are only a few of the factors which need to be considered in building a tire for the modern car and road.

The carcass or inner portion of the tire has likewise been improved. The principal difficulties in the old days were blowouts and failures resulting from separation of the carcass plies. The former have been largely eliminated by the replacement of the old-fashioned square-woven fabric or duck by the modern cord construction. The difficulties from separation have been largely eliminated by treatment of the cord to secure better adhesion to the rubber and by improvements in the rubber compound itself, resulting from the use of modern accelerators and antioxidants.

The chemical and engineering improvements in tire building have saved the consumer vast sums of money. Expressed in arbitrary units, the average tire cost per 100 miles for 4 tires was 750 in 1906, and by 1936 this had been reduced to about 40—a reduction of practically 18 to 1.

Let us consider the 16 years from 1920 to 1936. In 1920 the tire cost per 10,000 miles was estimated at $163. This figure was reduced at a fairly rapid rate, until in 1936 the tire cost per 10,000 miles was $38.30. If we assume that car registration and use would have increased as they did had the tire quality and price remained at the 1920 level, we can estimate the total saving to the consumer over

this period. This saving amounts to the stupendous figure of $35,083,000,000.

CONCLUSIONS

The discovery of vulcanization was one of the great inventions of modern times. It was basic, and it was of great and lasting importance. Although manifold improvements of Goodyear's invention have been made, it is still in use. Practically all the rubber goods that are now manufactured or that have been manufactured since 1839 are within the scope of his invention.

Of particular interest to the scientist is the extent to which this discovery stimulated research and development. As a result of the work of the lone inventor in the New England kitchen a hundred years ago, thousands of scientists and engineers throughout the world are engaged in improving and applying this invention. A century of development has not exhausted the invention.

While we are met today to celebrate the one hundredth anniversary of this discovery, this meeting is not the real memorial to this great inventor. "If you would see his monument, look about you" and observe the great industry which he founded, whose products have been vital to still greater industries and have contributed to the safety, comfort, and prosperity of mankind.

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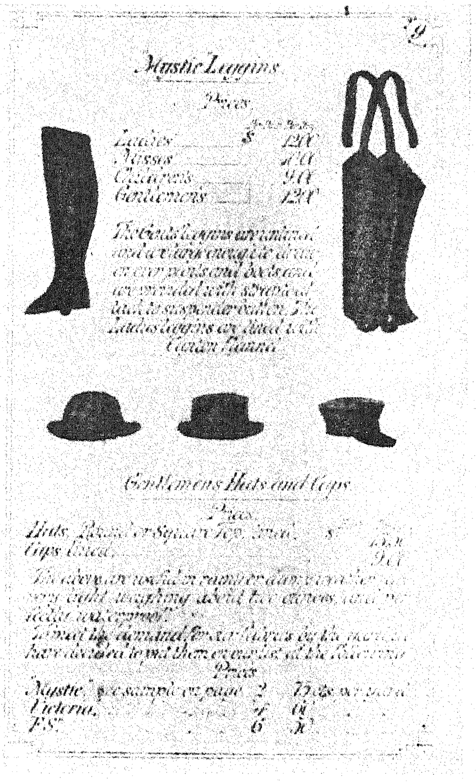

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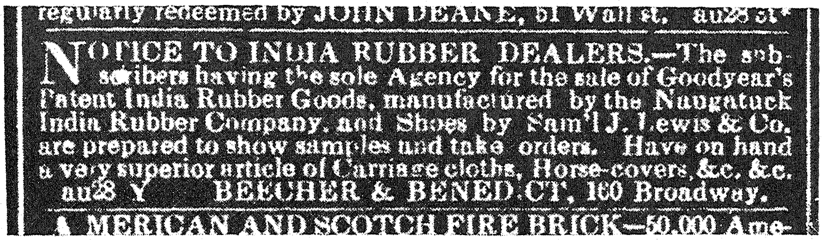
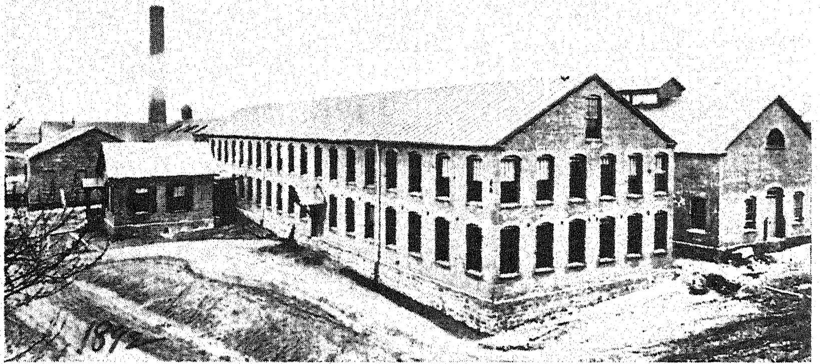


regularly redeemed by JOHN DEANE, 51 Wall st. au28 3t*

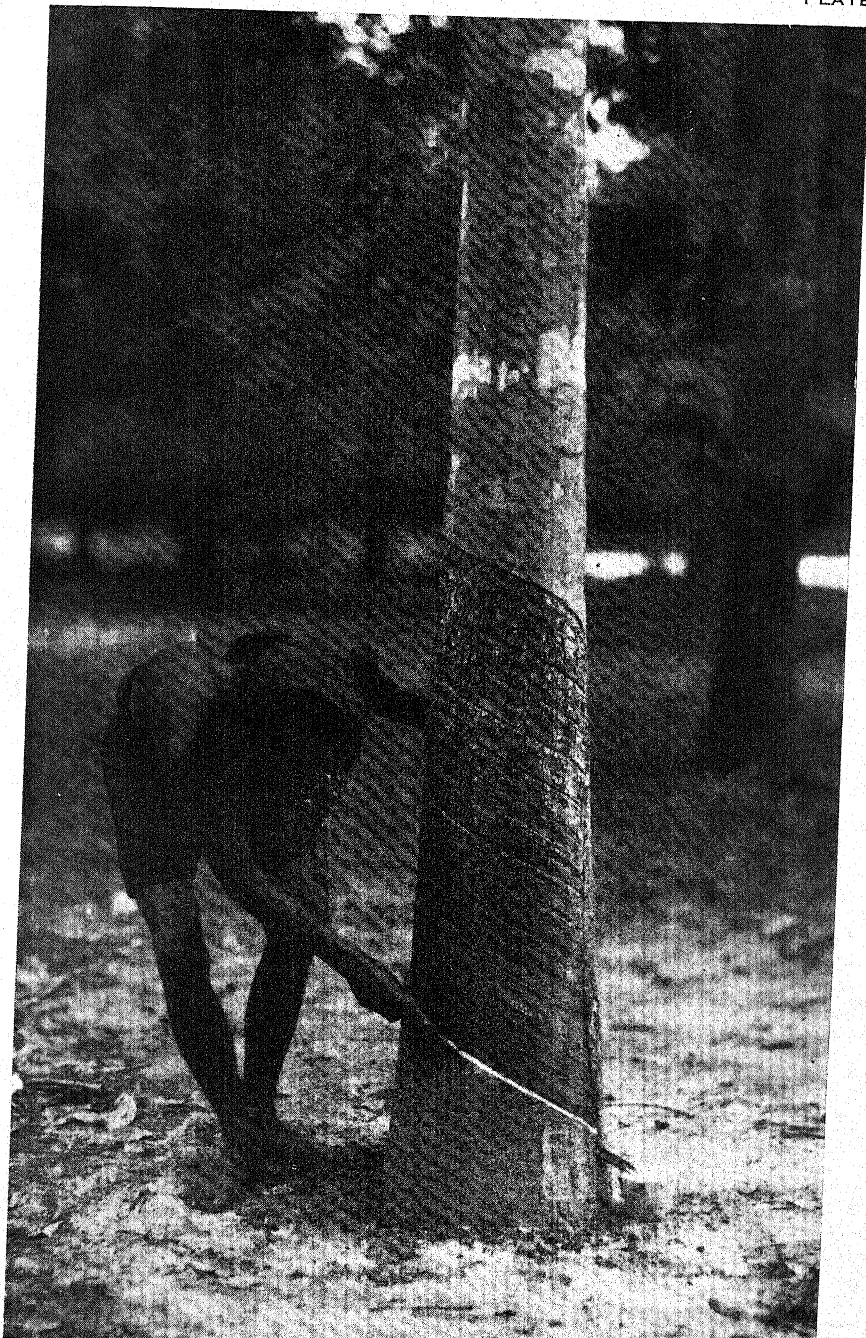
NOTICE TO INDIA RUBBER DEALERS.—The subscribers having the sole Agency for the sale of Goodyear's Patent India Rubber Goods, manufactured by the Naugatuck India Rubber Company, and Shoes by Sam'l J. Lewis & Co. are prepared to show samples and take orders. Have on hand a very superior article of Carriage cloths, Horse-covers, &c. &c.
au28 Y BEECHER & BENEDICT, 160 Broadway.

AMERICAN AND SCOTCH FIRE BRICK—50,000 Ame-

1. ONE OF THE EARLIEST KNOWN ADVERTISEMENTS RELATING TO VULCANIZED RUBBER, FROM THE NEW YORK DAILY TRIBUNE, AUGUST 30, 1844.

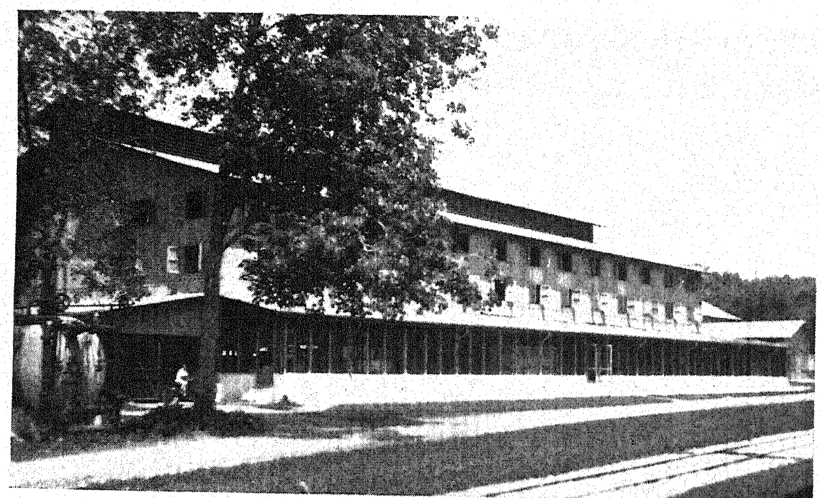


2. HARTFORD RUBBER WORKS IN 1892.



TAPPING A RUBBER TREE.

1. FIELD COLLECTING STATION, SHOWING NARROW-GAGE RAILWAY, LATEX TANK, AND ANHYDROUS AMMONIA CYLINDERS READY FOR LATEX PRESERVATION.



2. CREPE FACTORY, HOLLAND AMERICAN COMPANY, BOENOET, SUMATRA.

THE FUTURE OF MAN AS AN INHABITANT OF THE EARTH[1]

By Kirtley F. Mather

Professor of Geology, Harvard University

I

During the first decade or two of the current century, geologists, astronomers, and physicists engaged in many discussions concerning the future of the earth as an abode for life. Some believed that "the end of the world" was relatively close at hand; others, that the prospect for the future was to be measured in terms of hundreds of thousands if not of millions of years. As usual in scientific circles, there has emerged from the conflict of ideas during the years of discussion a general unanimity of opinion, and today the geologic outlook for the future of the earth is quite clear.

Since the turn of the century new methods of measuring the length of geologic time have been discovered and applied. New concepts of the nature and sources of energy have been proposed and tested. New data concerning astronomic space and the distribution of the stars have been obtained. Innumerable details of earth history have been deciphered to give a trustworthy record of the changes that the earth and its inhabitants have undergone in the past. The key to unlock the secrets of the future is now available in this knowledge of the past, and with our present understanding of the processes of nature that key may be intelligently used. All the evidence combines to lead us unmistakably to the conclusion that for many scores, if not for hundreds of millions of years to come, the earth will continue to be a comfortably habitable abode for creatures like ourselves.

Surface temperatures of the earth, the most important item in any consideration of its long-range habitability, are determined by the receipt of solar energy distributed through atmospheric agencies. For any given area of land the annual contribution of heat from the earth's interior, hot though it may be, is just about equal to the warmth received from the sun in 20 minutes by an equal area in equatorial

[1] Eighteenth Annual Sigma Xi Lecture, Columbus, Ohio, December 28, 1939. Reprinted by permission, with slight revision, from Sigma Xi Quarterly, vol. 28, No. 1, Spring, 1940.

latitudes under a clear sky at midday. The nineteenth-century picture of an earth, initially fiery hot but progressively cooling so that yesterday it displayed a glacial climate and tomorrow it will be too frigid to support life, may now be thrown into the discard. The earth will "grow old and die" only as a result of failure to receive adequate supplies of radiant energy from the sun. The prospect that the sun will "burn itself out" in a decrepit old age is so remote as to baffle all attempts to date that untoward event even by those who are expert in manipulating astronomic figures. Nor is there any likelihood that the space relations between earth and sun will change appreciably within scores of millions of years and put the earth either too close to the sun or too distant from it for comfort.

The lurid pictures of a sudden catastrophic debacle resulting from collision with some other heavenly body—comet, planet, star, or what you will—are products of a vivid imagination wholly without foundation in astronomic fact or theory.

The only plausible alternative to the conclusion that earth and sun will continue the even tenor of their ways for an inconceivably long period of time is that the sun will some day imitate the supernovae occasionally detected among the stars and terminate the existence of the entire solar system by a gigantic explosion. Precisely one such supernova has been observed within the galaxy of the Milky Way and several such in all the other galaxies of stars during the past few decades. The astronomers could, therefore, calculate for us the chances on a statistical basis that any individual star—the sun, for example—would suffer such a fate within any given period of time. The result would be a figure so infinitesimal as to set at rest the mind of even the most jittery of questioners. Pending the discovery of the kind of premonitory symptoms displayed by stars about to blow themselves to atoms, the best that can be done is to rest content in history. Since the earliest records of living creatures were left as fossils, if not indeed since the earliest sedimentary rocks were formed, the sun has faithfully maintained its energy output within a fairly narrow range and has given no evidence of any fluctuations that might suggest any significant change in its behavior.

The geologist may, therefore, turn with confidence from the long perspective of geologic past with its 1½ to 2 billion years of recorded earth history to a similarly long prospect for the future. Time is one of the most overwhelming resources of our universe.

It should not be inferred, however, that the earth will continue in the future to display the same environmental conditions as those which we enjoy today. The history of mankind thus far has been enacted against a background that in the full perspective of earth history is truly extraordinary. The geologic period in which we live

is a time of unusually rugged and extensive lands, with notably varied climate ranging from the glacial cold of Greenland and Antarctica to the oppressive warmth and humidity of certain equatorial regions. Such conditions have apparently recurred many times at long-spaced intervals since the oldest known rocks were formed, but added together the time thus represented cannot be as much as a fourth of geologic time. Much more characteristic of earth history as a whole have been the conditions illustrated by those periods when corals thrived in shallow seas occupying the site of Baffin Land and North Greenland, and coal-forming plants flourished on Antarctica. The probability is strong that eventually, say in 5 or 10 million years, the earth will display again the physical conditions of many past geologic periods that were characterized by broad low lands, wide shallow seas, and uniform genial climate.

But most of us have a greater interest in the next few centuries than in the subsequent millions of years. Minor changes in climate will doubtless occur just as they have in the last few thousand years. Unfortunately, or perhaps fortunately, there is no basis for prediction concerning their nature, whether for better or for worse. There is really no good reason for referring to the present as "a post-glacial epoch"; it may prove to be an interglacial epoch. But our ancestors weathered ice ages in the past, and presumably we are better equipped for such contingencies than they were. Should the average annual temperature of the earth as a whole be reduced something like 10° F. and remain at that lower level for a few millennia, it is likely that once more the greater part of Canada, the northern United States, and the Scandinavian countries would be buried beneath great ice sheets. But in consequence of the removal of water from the sea as vapor to form the snow to produce the glacial ice, considerable areas now shallowly submerged along the coast lines in middle and equatorial latitudes would emerge as dry land. Indeed, it is likely that the area of land suitable for human abode would be nearly or quite as great at the climax of a glacial period as it is today.

By the same token, the disappearance of existing bodies of glacial ice as a result of rapid amelioration of climate in the not-distant future would, if it occurred, be a decidedly mixed blessing. Return to the sea the water now imprisoned in the ice on the Arctic islands, Greenland and Antarctica without any compensating changes in crustal elevation, and sea level would be raised 150 to 160 feet the world around. Considering the number of people who now work or sleep in buildings in metropolitan communities not over 150 feet above sea level, the importance of such a change is readily apparent. But from the geologists' point of view these are relatively trivial

matters. With due deference to the nature of the climatic variations and geologic changes which are certain to occur in the next few thousand years, there is nothing to be expected from such sources that would seriously deter the human species from maintaining a comfortable existence on the surface of the earth for an indefinitely long period of time—a period to be measured in millions rather than in mere thousands of years.

II

At last, it is generally understood that man is a part of nature. He may be something more than an animal (that depends largely upon definition), but he is none the less truly a part of the animal world. Like the other inhabitants of the earth, man is a product of evolutionary processes operating on this particular planet.

We may be the latest product of the creative forces displaying themselves in the organic development taking place in this particular portion of the cosmos, but we have no reason to assume that we are the last achievement of those forces. Nor does the fact that man has arisen from a lowly origin through processes of evolution validate the optimistic inference that he will necessarily continue his progress to ever higher levels of activity. Evolution does not guarantee progress; it merely guarantees change. The change may be for the better or the worse, depending upon the conditions of time and place and the vitality of the individuals concerned.

The pages of Mother Earth's diary reveal an amazing and thought-provoking record of the progress of living creatures throughout the long eras of earth history. Again and again, in the procession of the living, dynasties of animals or plants have arisen from a humble origin to a position of world supremacy, maintained for a comparatively brief period and then lost forever. Some have disappeared entirely as their paths have led them off into blind alleys. Others have sunk to a low level and have continued a degenerate existence to the present day. A few have given rise to other and more efficient forms of life that superseded their predecessors as leaders in the procession. Gradually we are discovering some of the reasons for success and failure along the path of life. Beyond question, man may profit from these experiences of the past, if he uses the intellectual and moral resources which are available for him.

From the point of view attained through knowledge of geologic life development, man has today a unique opportunity to gain continuing security for himself and his progeny on the face of the earth, but whether or not he takes advantage of that opportunity is to be determined largely by himself. So far as we can tell, man is the first animal possessing the power to determine his own evolutionary

destiny, but there is nothing in the record which guarantees that he will use that power wisely.

The animal species that in the past have been able to maintain their existence for more than 2 or 3 million years are relatively few in number. Most of them were comparatively simple types belonging to the less highly organized branches or phyla of the animal kingdom. Many were inhabitants of the sea where environmental conditions were remarkably stable throughout long periods of time. Among placental mammals, the major subdivision of the vertebrates to which man belongs, there is no similar record of longevity. Except under extraordinary conditions of geographic isolation, no species of placental mammal has persisted more than 2 or 3 million years. No matter how successful it may have been temporarily in multiplying and spreading over the face of the earth, each has become extinct in a geologically brief span of time. Perhaps a half million years might appropriately be taken as the average "life" of a species in this group of highly organized and notably complex creatures.

But extinction does not necessarily mean failure; it has frequently indicated the acme of achievement. For example, some of the now extinct three-toed horses and four-toed camels passed on "the torch of progress" to their descendants, the one-toed horses and two-toed camels, and thus gained long-continuing security for their kind.

What then does the future hold for mankind? Genus *Homo* has already existed for 3 or 4 hundred thousand years; the species *Homo sapiens* has about 50 thousand years to its credit. If the average applies, we may expect nearly or quite a half million years more of existence for our kind and then either oblivion as we reach the end of a blind alley or progressive development into some type of descendant better adjusted than we to the total environmental factors of the time.

III

But does the average apply? Must man exit from the scene through either of the doors, that which closed behind the dinosaurs and titanotheres or that which opened before the three-toed horses and notharctines?

Most creatures have gained security by specializing in adjustment of structure and habit to particular environmental conditions, whereas man is a specialist in adjustability of structures and habits to a variety of environments. No other vertebrate can live as can he on Antarctic ice cap, in Amazonian jungle, beneath the surface of the sea, or high in the air.

Furthermore, man is the world's foremost specialist in transforming environments to bring them within the range of his powers. Far

more efficient than the beaver or the mound-building ant, he drains the swamp, irrigates the desert, tunnels the mountain, bridges the river, digs the canal, conditions the air in home, factory, and office.

As a matter of fact, adjustability to environment is accomplished more by controlling surroundings than by modifying internal organs or essential functions of the body. When we ascend with Major Stevens into the stratosphere, or dive with Dr. Beebe 500 fathoms deep off Bermuda, or live with Admiral Byrd through the long night of Little America, we take along with us a sample of sea-level atmosphere and temperate climate that is our real environment in a situation otherwise unbearable. Fur-lined parkas and tropical linen suits are but a medium for ensuring an immediate environment as nearly as possible like that of middle latitudes when living in polar or equatorial surroundings.

But regardless of interpretation of procedure, the result is clear. Man has placed himself in control of external conditions to an extent immeasurably greater than any other creature. He has practically "drawn the teeth" of environment.

Although we know little of the details, it is certain that most of the creatures of the past, who "have had their day and ceased to be," were forced into extinction by changes of one sort or another in their environment, changes which came with such relative speed that they were unable to make adjustment to them in time. Man need have no fear on that score.

IV

It is, however, immediately apparent that man's conquest of his surroundings has resulted from his clever use of things. Unless there is a ceaseless flow of cotton, flax, and wool, of coal, iron, and petroleum, of copper, lead, and tin, from ground to processing plant to consumer, he becomes a puny weakling. It is because he uses certain resources provided by his environment that he is freed from slavery to his environment. Are these resources adequate to keep him supplied with what he needs to maintain indefinitely the sort of existence to which he has accustomed himself?

There are two fundamental sources of the goods and the energy that man uses in the grim business of obtaining the sort of living that he apparently desires. On the one hand there is the farm and the waterfall, on the other there is the mine and the quarry. Things which grow in the field or forest, and power produced by falling water are in the category of annual income. Now that scientific research has made available the limitless quantity of nitrogen in the air for use as fertilizer, the resources of the plant and animal kingdoms are renewable; we use them, but we need never use them

up. In startling contrast, the resources of the mineral kingdom are nonrenewable; they are in the category of accumulated capital. Petroleum and coal, copper and iron, lead and vanadium, these and many other prerequisites of modern civilization have been accumulated by nature through hundreds of millions of years of geologic activity. Thanks to scientific research, man is exhausting that store of mineral wealth in a few hundred, or at most a few thousand, years. That inescapable fact is at rock bottom one of the most fundamental causes of economic distress, of war between nations, and of strife between classes.

Fairly accurate estimates of the world stores of many nonrenewable resources are now available. Take petroleum as an illustration. The known available reserves of petroleum beneath the surface of the United States total at present approximately 17 billion barrels.[2] Experts differ in their guesses as to the quantity of petroleum that may be discovered in the future in areas that have not yet been adequately explored with the drill, or in known fields by discovery of deeper reservoirs not yet reached by the deepest wells in those fields. There are also many varying shades of optimism and pessimism concerning the possibility of increasing materially the percentage of recovery of the oil present in a reservoir rock when penetrated by drilling operations. Estimates of the quantity to be added to our petroleum reserves from those two sources range from 7 or 8 billion barrels to 15 or 20 billion. I would incline toward the larger figures, considering them as maxima that are extremely unlikely to be exceeded. On that basis, the present store of available petroleum beneath the surface of the United States is 25 to 35 billion barrels. That is only about 30 times the annual domestic consumption of petroleum in recent years. The average annual production of petroleum in the United States during the 5 years from 1934 through 1938 was almost 1 billion 100 million barrels,[3] and the 1939 production exceeds 1¼ billion barrels. At the present rate of withdrawal, the domestic stores of this essential raw material would, therefore, be exhausted in less than a third of a century.

Data are not nearly so precise for the majority of foreign countries as for the United States. It is, however, fairly safe to conclude that the world stores of petroleum will last only something like 75 years at the present rate of withdrawal. With the possible exception of Mexico, no other country has been as successful as the United States in the attempt to exhaust its petroleum resources in the shortest possible period of time, but rapid progress toward that result is now being made in many regions.

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[2] "Petroleum reserves are estimated by Institute committee at new record total," Amer. Petroleum Inst. Quart., vol. 9, No. 2, p. 7, 1939.

[3] Statistics from Minerals Yearbook, published annually by the U. S. Bureau of Mines.

Lest we become too pessimistic in response to such unwelcome figures, we should promptly note that substitutes for petroleum are already known. Gasoline, fuel oil, and lubricating oil can now be manufactured from coal and other rocks rich in carbon, by processes of hydrogenation and polymerization. These are expensive processes and their products cannot now compete with the products from petroleum even in countries far removed, both geographically and psychologically, from the more productive oil fields.[4] They will, however, come into use more and more in the next few decades.

Enough bituminous and subbituminous coal is known to be available within the United States to meet the present annual demand for coal, plus enough to manufacture gasoline and fuel oil in sufficient quantity to meet current demands for at least 2,000 years. In addition there is enough oil shale—a rock rich in carbon but containing little or no oil—to meet present needs for petroleum products for at least 3,000 or 4,000 years.

Although petroleum affords an excellent illustration of the relation of nonrenewable resources to the activities of man, it is by no means typical of the items comprising nature's accumulated capital. For nearly all of the important nonrenewable resources, the known world stores are thousands of times as great as the annual world consumption instead of less than a hundred times. But for the few which like petroleum are not known to be available in such vast quantities, the story is much the same. Substitutes are already known, or potential sources of alternative supply are already at hand, in quantities adequate to meet our current needs for at least 2,000 or 3,000 years. There is, therefore, no prospect of the imminent exhaustion of any of the essential raw materials, so far as the world as a whole is concerned, provided our demands for them are not multiplied rapidly in the future.

That, of course, raises another question. Will the demand for nonrenewable resources increase materially in the future and thus hasten their exhaustion? Recalling the fact that the human population of the earth has increased almost fivefold in number in the last 300 years, we might well be fearful on that score. The study of current population trends, however, makes it readily apparent that the next few hundred years will by no means duplicate that record of the past. If present trends continue, the all-time maximum population of the United States will be attained about the year 1970 and will total little more than 150 million souls.[5] There-

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[4] Heald, K. C., Technology and the mineral industries. WPA National Research Project, Rep. E–1, pp. 27–31, 1937.

[5] Thompson and Whelpton, National Resources Committee, Population Statistics, vol. 1, National data, p. 9, 1937.

after, except for possible influx of immigrants from other countries, no further increase in numbers is to be expected.

Accurate figures are available for only a few other countries, such as England, France, and Germany, but there is a strong probability that the all-time maximum for the white races will be reached during the last third of the twentieth century and for the entire population of the earth before the end of the twenty-first century. Although the human family has doubled its numbers since 1860, it is extremely unlikely that it will ever reach twice its present number of approximately 2 billion. The pressure of demand for nonrenewable resources will not, therefore, become acute because of the increase in population in the near future. Mother Earth is a very wealthy benefactress, and our heritage of physical resources is far greater than ordinarily supposed.

There is, however, another reason why current consumption of nonrenewable resources cannot be taken as the basis for computing the "life" of such stores of basic materials. The demand for automobiles, telephones, radios, airplanes, and zippers, is today very unevenly distributed. Only a small fraction of the human population uses such things in any large amount. Other peoples are beginning to demand them and will do so increasingly as they become acquainted with the "benefits of civilization." In a few decades, unless we return to savagery, the world demand for many nonrenewable resources will be twice or thrice that of today.

Taking all these things into consideration, it would appear that world stores of needed natural resources are adequate to supply a basis for the comfortable existence of every human being who is likely to dwell anywhere on the face of the earth for something like a thousand years to come.

Even so, there may be found here an excuse for the policy of "grabbing while the grabbing is good" which motivates many individuals and nations at the present time. That excuse might, of course, be offset by the suggestion that there is no need to take thought for a morrow a thousand years hence, if we have any respect for the ingenuity of our remote offspring. There is, however, another phase of current trends in human history that should not be overlooked in this connection.

One hundred years ago, something like 80 percent of all the things man used had their source on farms; most of the energy used to do the work of the world came from the muscles of living beings and from falling water. Today only about 30 percent of the things man uses come from things that grow; most of the energy with which work is done comes from petroleum and coal. For a century or more, the policy has been to use relatively less of the annual income and more of the stored capital.

Now comes the change. Automobile steering wheels are made from soy beans; piano keys from cottage cheese; innumerable articles fashioned of plastics are produced in part from corncobs and alfalfa; multitudinous metal and rubber substitutes are synthesized from various farm crops. Energy is transmitted at high voltages for hundreds of miles from hydroelectric turbines. A considerable portion of the annual budget for research is being devoted to progress in the direction of using more of the renewable resources—man's annual income, and less of the nonrenewable resources—nature's stored capital.

What this new policy will mean is readily apparent. With progress along such lines, the pressure for political control of metalliferous ore deposits, coal fields, and oil pools is lessened. Much of the physical basis for international jealousy is liquidated. At last the intelligence of science may make it truly practical to beat our "swords into ploughshares, our spears into pruning hooks."

Again comes the insistent question from the pessimistic critic. Is there land enough? Is there sufficient fertile soil to provide adequate food and in addition the plant materials for the ever-expanding chemical industries? And again we hear the same reply. Yes, there is enough and to spare. J. D. Bernal computes from apparently valid data that the cultivation of 2 billion acres of land by the methods now in vogue in Great Britain would provide an optimum food supply for the entire population of the earth. "Two billion acres is less than half the present cultivated area of 4 billion 200 million acres, itself hardly 12 percent of the land surface of the earth." [6] And in this calculation no account is taken of the increased yields that may confidently be expected from the continuing research of agronomists, plant breeders, and experts in animal husbandry, not to mention recent developments in the new science of the soilless growth of plants. Evidently, the predictions of Malthus notwithstanding, mankind need have no fear that increasing populations will place an impossible burden upon the available sources of food. Human ingenuity, intelligent use of renewable resources, wise adjustment of structures and habits to environmental conditions, seem competent to dispel that dread shadow.

But these optimistic conclusions concerning the relation of man to the nonrenewable and renewable resources essential for comfortable existence are based upon world statistics. Obviously they do not apply with equal force to the economy of individual nations. No nation, not even the Soviet Union, Brazil, or the United States of America, embraces within its political frontiers a sufficient variety of geologic structures to give it adequate supplies of all the various

[6] Bernal, J. D., The social function of science, p. 347, New York, 1939.

metalliferous ores necessary as raw materials for modern industrial operations. The United States, for example, must import nickel, tin, antimony, chromium, and platinum if American manufacturers are to use those metals in the fabrication of articles essential to what we are pleased to call the civilized way of life.[7] Likewise, no nation enjoys a sufficient variety of climatic conditions to permit all kinds of foodstuffs to be grown on its farms and fields or gathered from its forests, and to allow the growth of all the various plants contributing raw materials to industry. The United States, again the most significant example for us, is forced to import all the bananas, coffee, tea, camphor, coconuts, flax, jute, quinine, rubber, and shellac consumed in this country, either from foreign countries or its own overseas possessions.[8] It is entirely possible that, within a few decades, substitutes of domestic origin may be available to take the place of many, or even all, of such commodities or that plant breeders and agronomists may find a practical way of extending the geographical limits of some of the plants whose products are considered essential so that any nation occupying a large fraction of any continent may actually be self-sufficient. But for the present and probably for a long time to come it is evident that every nation is dependent upon many other nations for the raw materials that it needs for its own industrial prosperity.

Perhaps the most important fact concerning the life of man today is this fact of interdependence. No nation, community, or individual can gain any lasting measure of security without taking that fact into consideration. The resources that man must utilize, if he wishes to escape the fate of his less intelligent relatives now known only by their fossil remains, are unevenly distributed and locally concentrated. The techniques of discovering and utilizing them are now fairly well known, but satisfactory procedures for making them and their products available to all members of the human family are not close at hand.

The very solution of the physical problems which man encounters in his attempt to maintain his foothold upon the earth brings him all the more forcefully into bruising contact with psychical and spiritual problems that must also be solved if he is to continue his existence on this planet. The critical question for the twentieth century is: How can 2 or 3 billion human beings be satisfactorily organized for the wise use and equitable distribution of resources that are abundant enough for all, but are unevenly scattered over the face of the earth? Clearly, the future of man depends upon finding and applying the correct answer to that specific but far-reaching question.

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[7] Emeny, Brooks, The strategy of raw materials, p. 26 and chart facing p. 29, New York, 1937.

[8] Ibid., pp. 26–37.

Man is not only a specialist in the art of coordinated activity, but the trend toward organization is recognizable in the entire development of cosmic administration. Electrons, neutrons, and protons are organized into atoms, atoms into molecules, molecules into compounds. Some of the compounds prove to be cells, and these are organized to form individual plants and animals. Latest of all in the history of creative evolution certain individuals have been organized into societies. Transcending all that has gone before is the development of human society, obviously the most difficult, but at the same time potentially the most glorious organization yet attempted.

Two antagonistic alternatives present themselves as possible bases for this organization. The issue between the two has never before been so clearly drawn as it is today. The social group, whether it be the family, the industrial or commercial company, or the political unit, may be organized on the principle of regimentation, or it may be developed according to democratic principles. Both methods are being tried under a variety of conditions, and each has something to be said in its favor. But both cannot be equally conducive to the continuing existence of mankind. One or the other must be selected as the basis for the future security of man.

If regimentation be the choice, then the great mass of humankind must be trained for obedience—blind, unquestioning, but superbly skillful obedience. The educator becomes the intellectual and spiritual counterpart of the drill sergeant in the army. This is no menial task, nor is its objective a mean one. Skill is a commodity of which there is never likely to be an oversupply. On the other hand, if democracy be the choice, the great mass of humankind must be trained for wise, self-determined cooperation. Precisely those qualities of mind and heart which have long been extolled in Christian doctrine must be developed to the fullest possible extent. Not only skill but also the ability to govern oneself, the eternal prerequisite for freedom, must be developed in each member of the group.

Insofar as physical existence is concerned, there would seem to be little or no choice between these alternatives. Human nature being what it is today, perhaps the regimentation of society may temporarily be the more efficient method. But the full circle of organic law embraces more than mere existence. From the continuity of the evolutionary process, there has emerged a creature who is aware of vivid values in life that may be found beyond the goods necessary for comfortable existence. Ideas and ideals are powerful determining factors in the world today, and among them the ideal of freedom for the individual in the midst of social restraint is the most vital and compelling of all. Though it baffle our scientific tools for measurement, it is nonetheless a reality.

It is in the yearning for freedom, the love of beauty, the search for truth, the recognition of moral law and in the awareness of spiritual forces that human nature is distinguished from all other sorts of nature. Man shares with other animals the need for satisfactory economics, for adequate food and shelter, for the goods essential to existence, but his needs transcend these physical factors because his nature differs from theirs. Probably nine-tenths of all the words that have been used since the dawn of speech in reference to "human nature" have referred to those elements in the nature of man that are shared with other animals rather than to those that are man's unique possession. It would be far better to concentrate upon the latter and thus to distinguish human nature from animal nature.

Regimentation may be good for man as an animal; through that type of social organization his need for goods may be efficiently supplied. But regimentation is certainly not good for human nature as thus distinguished. Experience verifies what wisdom foresees; regimentation stultifies the spirit, destroys personality, standardizes thought and action. Worst of all, regimentation means stagnation of the creative process and, as we have seen, stagnation among the more complexly organized vertebrates has led inevitably to extinction. If man attempts to live by bread alone, mankind commits collective suicide. Apparently the best and perhaps the only chance for mankind to succeed in the quest for security is through progress in the art of living on a high spiritual plane rather than through exclusive attention to the science of existence on a purely physical level.

V

To put this same thought in more specific terms, it means that coordinated activity directed toward efficient organization of individuals must become cooperative activity directed toward the enrichment of personality within an efficiently organized society. This requires both intelligence and good will.

Fortunately, these characteristics are uniquely developed in the species of placental mammal with which we are preeminently concerned. Man is a specialist in the use of both. The trend of the past 5,000 years may well continue, despite numerous temporary setbacks, throughout the next few centuries at least.

It is sometimes suggested that because man has specialized in brains, brains may cause his downfall, just as presumably the overspecialization in external armament contributed to the downfall of certain herbivorous dinosaurs. That argument by analogy is, however, heavily punctuated with fallacies. There is as yet no evidence that mankind is weighted down with a superabundance of intelligence. On the contrary, it is failure to act intelligently that endangers indi-

viduals and groups in the midst of competition. To see in advance the remote consequences of contemplated action is an ability that ought to be increasingly cultivated rather than scouted as a menace.

There seems to be no good reason why a sound mind should not be accompanied by a sound body. If the number of psychopathic individuals is increasing in this high-speed, technologic age, it is a challenge to be met not by bemoaning the imminent collapse of civilization but by intelligent adjustment of habits and activities to the new demands of the new times.

Once the commitment is made to the belief that the cooperative way of life offers the best chance for the future security of man as an inhabitant of the earth, the need is greater for intelligence to be used as a guide for good will, rather than for good will to be applied as a brake on any possible increase in intelligence.

The roots of self-centered individualism may be traced backward for at least 600 million years in the record of geologic life development, whereas our heritage of social consciousness dates from a time only about 60 million years ago when gregarious instincts became clearly evident among placental mammals. That trend is, however, especially apparent in the group from which mankind has stemmed.

Man is still in the stage of specific youth. His golden age, if any, is in the future rather than in the past. Human nature is still sufficiently plastic and pliable to permit considerable change, notably in this important area of attitudes and relationships wherein the increase of good will as a motive for action seems most likely to result in beneficial adjustments to the new factors in the environment.

In thus seeking a satisfactory coordination of intelligence and good will, it becomes necessary for research scientists to give more thought than has been customary in the past to the social consequences of their work. They share with statesmen, politicians, educators, and all molders of public opinion the responsibility for determining the uses to which the new tools provided by scientific research are put. As scientists, they should continue to seek truth regardless of its consequences and to increase human efficiency in every possible way, but as members of society, as individual representatives of a species seeking future security as inhabitants of the earth, they must also do their utmost to ensure wise use of knowledge and constructive application of energy.

There is a real difference between the so-called social sciences and the natural and physical sciences that has an important bearing here. It is not that there is anything unnatural about the social sciences. Man is a part of nature, and the study of human society is just as truly natural science in the real sense of the term as any other study. The difference arises from the peculiar factors and particular func-

tions pertaining to the cooperative way of life. Whereas the scientific use of things may be achieved through the efforts of a very small minority of the citizens, provided with adequate facilities for research, the scientific organization of society in a democracy can be achieved only when the majority of its citizens have the scientific attitude toward social problems and act in accordance with that attitude of mind. In other words, only a few physicists, chemists, and technologists are required for the mastery of our physical environment, but for victory in the struggle with ourselves every man must be his own sociologist.

Although this places upon the forces of education a Herculean task, it is not nearly so impossible an assignment as at a first glance it might appear to be. In the first place, the responsibility upon the individual citizen is rarely that of designing a new social structure or charting a new program for society. Almost invariably it is his duty merely to select from many plans, programs, or proposals the one that seems to him most likely to produce the most desirable results for all concerned. In the second place, scientific habits of mind have already been developed to a greater extent than is ordinarily recognized. The garage mechanic attacks the problem of a balky automobile in a truly scientific manner. The salesman uses psychology in planning his approach to a difficult prospect. The housewife thinks scientifically when about to concoct a new dessert or redecorate the living room. In most cases, it is only necessary to apply in the area of social relationships the same habits of mind that have been followed in the area of individual behavior.

VI

In conclusion, the outlook for the future of man as an inhabitant of the earth is far from pessimistic. If certain tendencies already developing are encouraged and certain resources already available are capitalized to the full, there is good reason to expect that mankind will maintain existence and even live happily for an indefinitely long period of time. The opportunity is his to demonstrate the intrinsic worth of biologic phenomena and thus to justify the vast expenditure of time and energy involved in organic evolution. With greater emphasis upon the development of intelligence and good will, he may achieve that which the temporarily triumphant dynasties of the past have failed to achieve. Thus the geologist may turn from the long perspective of geologic history to the enticing vista of the geologic future of earth and man with high hope and even with confident assurance.

THE SEARCH FOR OIL [1]

By G. M. Lees

[With 4 plates]

Under the title of "The search for oil" I have given myself the task of setting down, first, a short review of the present distribution of oil production throughout the world; second, a description of the general nature of oil fields and of modern methods of exploration; and third, an account of current exploration for oil in Asia. It is well known that the search for oil in all parts of the world is more active at the present day than ever before, and yet at the same time there is such a great potential overproduction from existing oil fields that the economic structure of the industry is only supported by coordinated restraint on the part of the producers. For example, the great oil fields of the United States were given a fortnight's holiday in August 1939 in order that an embarrassing situation caused by uncomfortably full surface storage might right itself. And yet one frequently reads in current journals of a coming shortage of oil supplies and of there being only 15 years of oil reserves in sight. How are these apparent paradoxes to be reconciled?

THE WORLD'S OIL PRODUCTION

The table (p. 235) gives the distribution of present production, total production up to date, and an estimate of proved reserves of various countries in the world.[2] The outstanding points which emerge from a study of it are, first, how small a number of countries in the world contribute importantly to the total oil supply, and second, that of these only two, the U. S. A. and the U. S. S. R., are themselves important users. And what a curious, almost freakish, distribution! It is easy to answer that the distribution is controlled by geologic circumstances, but one's innate trust in the law of averages handicaps one in believing that Providence really has endowed the U. S. A. with such a dominating proportion of the world's oil.

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[1] Reprinted by permission from the Geographical Journal, vol. 95, No. 1, January 1940.
[2] Garfias, Amer. Inst. Min. and Metallurg. Eng., Ann. Meeting, New York, 1939.

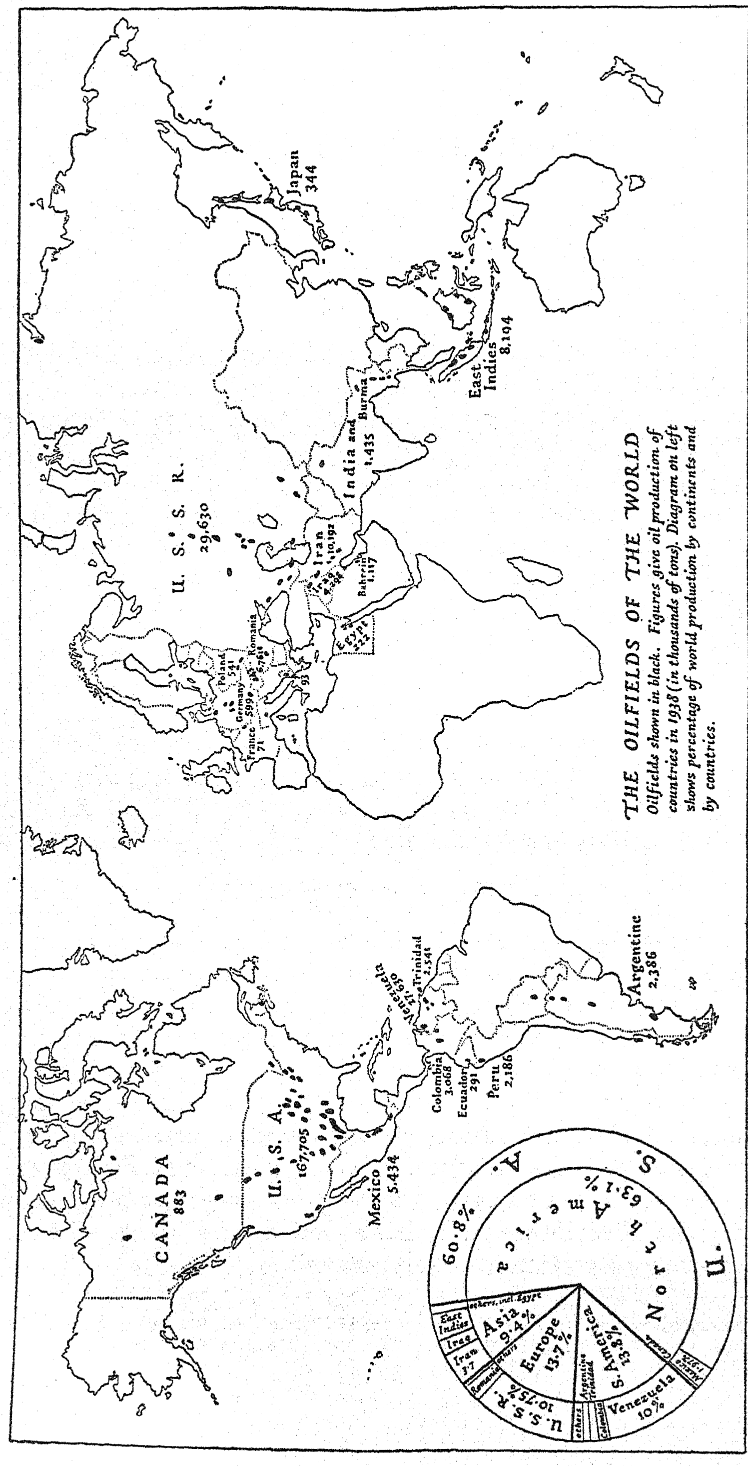


FIGURE 1.—The oilfields of the world.

THE NATURE OF OIL FIELDS

Before continuing with this topic, and certainly before commencing an examination of the extent of proved reserves, I shall to a certain extent digress by describing the general nature of oil fields. For many years an acute controversy raged over the origin of petroleum, whether inorganic or organic, but of recent years evidence in favor of organic origin has become overwhelmingly strong. The trouble is that oil, being mobile, does not necessarily remain where it was formed and so allow one to examine the circumstances of its birth, as, for example, is the case with coal. Being a fluid, it can, and often does, migrate considerable distances vertically and laterally through the rocks, and one can seldom be quite sure of its original provenance. In general terms it is now thought that oil is formed by slow chemical or biochemical decomposition of the remains of lowly forms of organic life entombed in sedimentary rocks. Circumstances may vary considerably, but marine or estuarine conditions seem a necessary condition for the formation of oil in important quantity. This means that these organic remains, whether seaweeds or sea grasses of whatever form, marine animal elements such as foraminifera or plant life such as diatoms, are entombed in the bottom sediments of shallow seas or estuaries under stagnant bottom conditions which prevent complete decomposition before burial. Subsequently this organic material is transformed, perhaps by bacterial action or perhaps by age-long chemical change, into small globules of oil and gas; and in the course of geological time, as the original muds are being compacted into shales or marls, these globules, together with a much greater quantity of original water, are squeezed out and find a lodging in any convenient porous stratum such as a sand lens or a porous limestone.

In this way a water-bearing porous stratum may carry globules of oil and bubbles of gas, though widely dispersed. The next phase is the concentration of this oil from a state of fine dissemination into what we in our short-term egoism call commercial oil fields. This concentration is primarily brought about by the force of gravity. Oil, being lighter than water, floats, and so the globules trickle up to the top of a given layer of sand, say 50 feet in thickness, until their further upward progress is sealed by an impervious cover of rock such as shale. If this rock layer were itself horizontal, further movement of the oil would then stop, but this is seldom the case. In the course of geologic time the layers of rock become tilted by processes of mountain building, and in front of the major mountain ranges of the world the stratified rocks are thrown into a series of folds or anticlines (fig. 2). The crests of these anticlines become oil traps for oil and gas which float up within a porous layer from

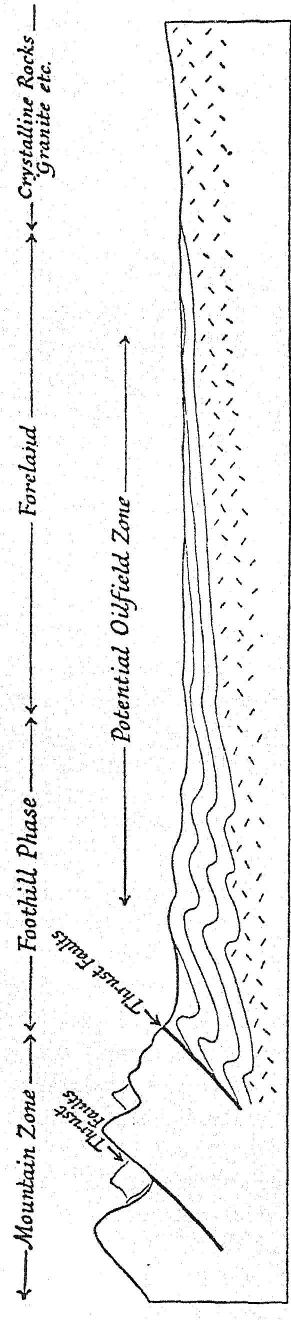


FIGURE 2.—Generalized cross section of a mountain system from high mountains to crystalline foreland.

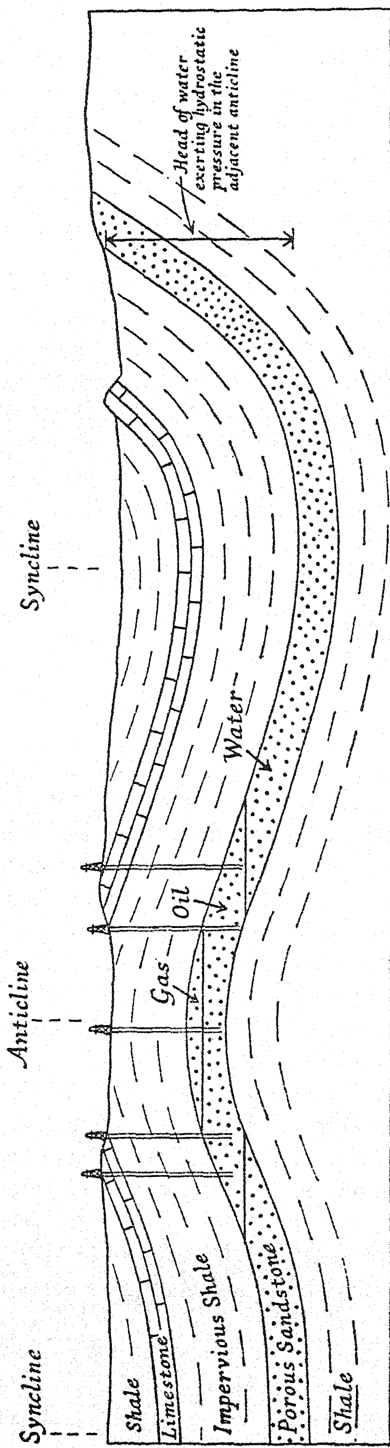


FIGURE 3.—Geological vertical section through a typical anticlinal oilfield.

the adjacent troughs or synclines. The oil thus concentrated along the summit of such an anticline is actually floating on water within its porous reservoir rock, as illustrated in figure 3, and if gas is present in greater quantity than can be kept in solution in the oil the excess gas fills the highest part of the anticline, forming what is known as a gas cap.

The most usual type of oil accumulation is under such anticlinal control. Another type is where the oil is concentrated in the higher edge of a tilted sandstone wedge, and such an occurrence is called a stratigraphic trap or shore-line oil field. Yet further types are where an intrusive body of salt gives a domed structure to the adjacent strata, or where the sealing of a sandstone layer is caused by a fault.

Petroleum production (in long tons)

	In 1938		Total to end 1938		Proved reserves [1]
		Percent		*Percent*	
U. S. A	167, 705, 000	60. 81	3, 026, 000, 000	64. 19	2, 000, 000, 000
U. S. S. R	29, 630, 000	10. 75	575, 000, 000	12. 20	700, 000, 000
Venezuela	27, 657, 000	10. 03	242, 000, 000	5. 14	
Iran	10, 192, 000	3. 70	125, 000, 000	2. 65	
Dutch East Indies (British Borneo and Sarawak)	8, 194, 000	2. 97	119, 000, 000	2. 52	
Rumania	6, 761, 000	2. 45	119, 000, 000	2. 52	1, 580, 000, 000
Mexico	5, 434, 000	1. 97	271, 000, 000	5. 75	
Iraq	4, 298, 000	1. 56	19, 000, 000	. 40	
Colombia	3, 068, 000	1. 11	33, 000, 000	. 70	
Trinidad	2, 541, 000	. 92	23, 000, 000	. 49	
Argentina	2, 386, 000	. 87	25, 000, 000	. 53	
Peru	2, 186, 000	. 79			
India and Burma	1, 435, 000	. 52			
Bahrein	1, 117, 000	. 42			
Canada	883, 000	. 32			
Germany	599, 000	. 22			
Poland	541, 000	. 20			
Japan and Taiwan	344, 000	. 12	137, 000, 000	2. 91	80, 000, 000
Ecuador	291, 000	. 11			
Egypt	222, 000	. 08			
Albania	93, 000	. 03			
France	71, 000	. 03			
Saudi Arabia	66, 000	. 02			
Hungary	43, 000	. 02			
Other countries	48, 000	02			
Total	275, 805, 000		4, 714, 000, 000		4, 360, 000, 000

[1] The figures in the last column are the proved reserves on Jan. 1, 1939, estimated by Garfias.

The oil in its reservoir is under a certain pressure governed by the regional hydrostatic conditions (fig. 3), and it carries gas in solution either saturated to this pressure or some lower pressure, and it is the combination of the hydrostatic pressure and gas content which causes gushers or fountains of oil at the surface. The homely ex-

ample of the soda-water syphon can be quoted as an illustration of the process. When the well is drilled the oil may flow at the surface under great pressure or it may flow gently under low pressure, or it may rise to a certain level in the hole and no higher, from which level it must be pumped to the surface—all depending on local pressure conditions and gas saturation pressure. The life history of an oil field after discovery is first exuberant youth, then, as initial vitality declines, sober middle age, followed by a long period of tired old age with ever-decreasing productivity. The best results are obtained under conditions of controlled production whereby the initial flow is throttled down and both the gas and the water pressures, which are the motive forces of the oil production, are carefully controlled. A carefully managed oil field may be made to produce several times as much oil as it would under wasteful conditions of control.

After complete exhaustion, what is the corpse of an oil field like? The porous rock skeleton remains unaffected, as the oil has been drained only from the interstices between the sand grains of a sandstone or from between the grains or fissures of a limestone, and a large amount of oil still remains wetting the surfaces of these grains. Only about 20 or 30 percent, on an average, of the total oil of a reservoir can be produced by ordinary means, but more is possible where a competent natural or artificial water flush or drive is operative. In some cases, particularly where the reservoir rock is a limestone, too rapid oil production may draw water up the fissure system and cause premature and unnecessary ruin of an oil field; this happened in Mexico in 1922, as some investors may remember to their cost. Eventually it may be economically possible to mine the oil sands of exhausted oil fields to recover the residual oil, a process which, aided by high protection, is now in operation at Wietze in Germany.

Oil fields vary within wide limits both in size and in productivity. The world's record for size is the oil field of east Texas, which, in its 9 years of life to date, has produced 205,200,000 tons of oil and is credited with an ultimate possible total of 650 million tons. It has a length of about 40 miles, an average breadth of about 7 miles, and 25,800 wells have been drilled. The world's depth record is a well in California which reached 15,004 feet. Such spectacular figures however are the journalistic scoops of the oil world and give a distorted impression of the average condition. Oil fields may be classified as giants, major fields, and average fields. In the first category, and not more than about a dozen oil fields in the world belong here, are fields which will give an eventual total of 100 million tons or more. Major oil fields, and even these are not too plentiful, are from 5 to 100 million tons, and average fields are under the 5-million mark.

The number of oil fields in the world in the average category is about 1,500, and the average size is about 500 acres, average depth about 2,500 feet, average initial production per well about 10 tons per day, and average ultimate production about 2 million tons.

So much for the nature of oil fields. I shall now refer back to my table of production distribution and discuss the question of proved reserves and the prospects of the future. In the table the U. S. A. is credited with proved reserves of 2,000 million tons, or, in other words, about 12 years of supply at the present rate of production. This, however, refers only to proved reserves, that is, the estimated production yet to be drawn from known fields, and no allowance is made in this figure for new discovery. The rate of new discovery in the States is still a formidable one. But the present decade will show a considerable reduction in this respect on the previous, and this is in spite of great improvements in the technique of oil finding and of the depth capacity of drilling machinery (fig. 4).

Many estimates have been made in the past of the total oil reserves, as distinct from proved reserves, of the U. S. A., and each estimate has in turn been disproved by subsequent experience, with the result that there is frequently a disinclination on the part of many to trust the common anticipation of a coming shortage of oil, a disbelief which gains strength from the large potential overproduction at the present day. But notwithstanding past errors, there is no doubt on the part of all responsible American oil geologists, and my own study of the situation adds confirmation, that the bulk of American oil has already been discovered. Fifteen years' supply is already in sight and new discovery may provide for perhaps a further 10 years, perhaps 15 years, or perhaps 20 years, but that is the order of expectation. One must not conclude from this that the oil fields of the States will be exhausted within 20 to 30 years from now, because the rate of decline of oil fields is so slow that it would be impossible to exhaust them in such a short time. But what it does mean is that there will be a decline in total production within a measurable number of years, and a realization of this salient fact is important for the theme of my paper. It is the realization of this fact by the large and powerful American oil companies that has caused them to intensify their search for new reserves of oil elsewhere in the world, and to compete actively for new concessions wherever they are to be had and in any countries having even remote potentialities, knowing that all the more obvious prospects have been taken up and explored long ago.

Before leaving the U. S. A. I must answer my earlier question of why that country should have such a dominating position in the world of oil. The answer is twofold: they actually have an enormous oil supply, and they have tried harder than any other country.

I have already explained how oil fields occur in sedimentary basins, in the folded zones in front of mountain ranges, or in shore-line zones. The U. S. A. have a variety of geologic provinces of various ages fulfilling these conditions, but that is not all. They have tried harder. Every modern device of exploration is rapidly accepted and utilized, but supplementary to both geologist and geophysicist is the wildcatter or the speculator who drills on "hunch" alone. And the wildcatter fulfills an important function. He has not only directly discovered perhaps 20 percent of the total oil of the States, including the biggest of all oil fields, that of east Texas, but he has also indirectly contributed to a greater degree in that both geologist and geophysicist make use of the information from his unsuccessful wells as a guidance for their own locations. A further important factor is that small oil fields which can be produced with profit in an intensively industrialized country would not be economically possible if remote from markets or existing pipe lines.

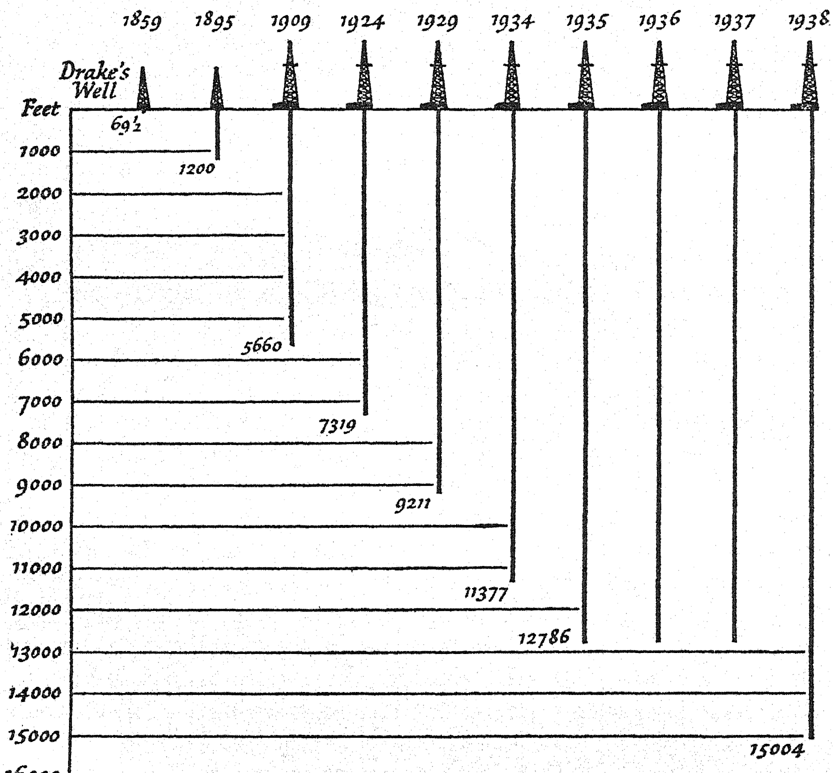


FIGURE 4.—Diagram showing increase in depth of the world's deepest wells. (From Pogue, J. E., Economics of the petroleum industry, 1939.)

EXPLORATION METHODS

I have already explained in general terms the geologic characteristics of oil fields and I shall now describe briefly the principles and working methods which lead up to the discovery of new oil fields.

In the first instance a country to be investigated must be examined in respect to its general geologic nature. Countries that are composed exclusively of igneous or metamorphic rocks, that is to say, of granite or schists or gneisses, have no possible hope of containing any oil, and attention is directed solely to areas having a cover of sedimentary rocks (fig. 2). The strata must have had a favorable development for the original formation of oil, must contain suitable porous rocks to act as oil reservoirs, and must be folded into a suitable pattern for the accumulation of important amounts of oil. Unfortunately, science has not yet progressed so far that we can with certainty recognize primary oil-source rocks, but we can say that certain groups of rocks may come into this category and that others certainly do not; for this reason the oil geologist is greatly encouraged by outward indications of the actual, as distinct from the theoretical, existence of petroleum in the form of oil seepages, oil-impregnated rocks, or of oil residues.

A preliminary geologic survey investigates these various points and, in the case of relatively unknown countries, it is usually necessary to make a comprehensive geologic map at the outset and an intensive study of structural and stratigraphic conditions must be made. During the early stages of this exploration, aerial photography has been used to great advantage during recent years. Not only can topographic maps of sufficient accuracy for the purposes required be drawn from these photographs but, in addition, much geologic information can be deduced from expert stereoscopic examination of pairs of photographs. Rock outcrops can be marked, dip and strike determined, and faults detected; and the outline geologic map thus produced is of great assistance to the subsequent ground survey. In many instances, particularly where outcrops are poor, structural deductions, which would be difficult or even impossible to make on the ground, are possible from a study of drainage pattern or of hill forms from the photographs.

A geologic survey is dependent on sufficient rock outcrops, and in many foothill zones in front of main mountain systems, particularly in arid countries, the solid geology is well exposed. But sedimentary basins frequently fall in low-lying areas or alluvial plains, and in this case the solid rock structure is completely obscured from view by a mantle of alluvium, marsh, or tropical forest. When this is the case the capacity of the geologist is limited and he has to call on the assistance of the geophysicist for further help. By

geophysics is meant any physical method of investigating the subsurface structure of the earth, and applied geophysics in this sense is a product of very recent years.

The methods used are based on gravimetric, seismic, or electrical principles, each of which has advantages by certain circumstances. The gravity method was the first to be developed, and an extremely sensitive torsion balance, invented by the Hungarian scientist Baron von Eötvös, was first used for oil finding by Dr. H. de Böckh, also a Hungarian. During the last few years a new type of gravity instrument, called the gravimeter, has been extensively used, and although the physical principles of the instrument are considerably different, the final result for practical purposes is similar. These gravity instruments measure minute differences of the force of gravity throughout a given area, and it has been found that a large anticline, the core of which has rocks of higher specific gravity than its flanks, causes at the surface a slight increase in the value of gravity as compared to its surroundings. The effect may range from a few milligals to perhaps as much as 50 in the case of a major unit, but as a milligal is 0.001 cm./sec.^{2}, or approximately one-millionth part of the total force of gravity at sea level, it will be readily appreciated that the instruments used are most highly sensitive and their manipulation is a matter of extreme care and skill. An inverted gravity result is obtained in the case of salt domes where the salt core of the dome is of a lighter gravity than the surroundings, and in this case the target that is required takes the form of a gravity minimum.

The geophysical method which is now perhaps the most usual is based on seismic principles. This is a type of echo sounding, but subsurface conditions are naturally much more complicated than is the case with the marine echo sounder. A small explosion is fired in a shot hole of 50 or so feet depth and the return vibrations, reflected from various harder rock groups at depth, are registered by groups of seismometers. The results are correlated and depicted in the form of contour maps which show the structural attitude of the various reflecting horizons. In some cases however the composition of the rocks is not suitable for giving satisfactory reflections and it is necessary to use the refraction method. Its use requires a much larger charge of explosive, which in exceptional circumstances may be as much as 1 to 2 tons of gelignite, and the seismometer instruments are placed much farther from the shot point than is the case with the reflection method, the distance being as great as 10 to 15 miles.

In other cases certain electrical methods of surveying are used, although the conditions suitable for their employment are less frequent than with the methods already described. The electrical method measures the relative resistivity and conductivity of the various groups of rocks and provides a contour map of their structure.

These various geophysical methods do not, of course, determine directly the existence or otherwise of underground oil, but they do assist greatly in providing a structural picture of the subsurface by which deductions regarding the probability or otherwise of oil may be made, and they assist greatly in locating exploration wells to best advantage. They are, however, far from being a universal panacea and there are frequently many difficulties of interpretation of the results obtained.

During recent years a geochemical method has been attempted which deals more directly with underground oil. Small quantities of surface rocks or soils are analyzed for their hydrocarbon gas content, and it has been found that minute escapes of gas, not detectable by ordinary means, may give a clue to underground oil accumulations. This method is at present at a stage of early development and much research work is required before it can be looked upon as an established method for routine application.

The hazards of oil exploration are well known to the investing public, but the reasons for them are probably less well appreciated. After as complete a survey of a potential oil region as is possible, using all geologic and geophysical assistance, the average chance of success of an exploration boring cannot ever be rated, on the basis of past experience, as better than perhaps one in ten; but past experience has also shown that if financial resources can stand the strain of the nine unsuccessful efforts the reward from the fortunate tenth may be expected to give sufficient compensation.

OIL EXPLORATION IN ASIA

The intensity of exploration in various parts of Asia has considerably increased during recent years, and most of the large British and American oil companies are involved. British and British-Dutch companies have been actively engaged in the Asiatic field for many years, and many important oil fields have been discovered and developed; but the new interest now being taken by American companies is, as I have already said, based on the belief that American oil reserves will not stand the present rate of production for many years. The necessity to discover and develop additional reserves well ahead of demand forces the American companies to carry the search to whatever parts of the world offer even remote prospects. Exploration work under modern conditions is a lengthy and expensive undertaking, and the interval between the commencement of an examination of a new concession and the time when an oil field is found and sufficiently developed for export may cost many hundred thousand pounds in money and 5 or even 10 years in time. For this reason exploration work must be years ahead of the neces-

sity for the products which may emerge therefrom, and in many cases big oil companies reduce the hazards of expensive undertakings by pooling their resources and cooperating in the exploration surveys.

The countries, other than in North and South America and Europe, where exploration is at the present moment most active are Egypt, Sinai, Palestine, Syria, Arabia, Iraq, Iran, Afghanistan, Asiatic U. S. S. R., India, Burma, Dutch East Indies, Borneo, Sarawak, Dutch New Guinea, British Mandated New Guinea and Papua, Australia, and New Zealand. In many cases the chances of discoveries of importance are extremely speculative, but nevertheless wherever theoretical possibilities exist they are being exhaustively investigated. A large expenditure of money and effort may give insufficient or completely negative results; as examples may be quoted an American company's recent experience in northeastern Iran and Afghanistan and the Shell Company's exploration survey in Papua, which was abandoned after £433,000 had been expended. An example of the opposite experience is the spectacular success of an American company at Bahrein. It would be quite impossible in the course of this paper to describe in any detail the progress of these extensive surveys, but a short résumé of the present position would probably be interesting.

EGYPT, PALESTINE, SYRIA

The first phase of exploration in Egypt was in the years just before and after the World War of 1914–18, when about 40 exploration wells were drilled in various places throughout the Gulf of Suez littoral. Two oil fields were discovered, Jemsa and Hurghada. After a very few years of spectacular life the Jemsa field declined and was abandoned, but the Hurghada field, discovered in 1913, is still producing, although at a steadily declining rate. Eighteen months ago, however, the persistent effort of the Anglo-Egyptian Oilfields, Ltd., was rewarded with a new discovery at Ras Gharib, 115 miles southeast of Suez. This discovery has greatly stimulated exploration in other parts of the Gulf of Suez area, northern Egypt, and Sinai. Geologic and geophysical surveying is being actively carried out by British and American companies, and several new exploration wells are in the course of drilling.

Geologic and geophysical exploration has been active in Palestine for a number of years, and several concessions have been granted in the coastal zone and in the Dead Sea region. Drilling is contemplated, but progress has been retarded by the recent troubles in Palestine. It is interesting to recall that the bituminous occurrences in and adjacent to the Dead Sea gave rise to its ancient name of Lacus Asphalticus.

Two deep wells are at present being drilled in Syria, one at Derro, close to Deir ez Zor, and one at Dubeyat, east of Palmyra. As yet no success has been recorded, but the work is continuing. Other exploration wells are also contemplated as the result of extensive geologic investigations.

IRAQ

The construction of the pipe-line system from Iraq to the Mediterranean has been one of the most spectacular engineering achievements of recent years. It connects the Kirkuk oil field, discovered and developed by the Iraq Petroleum Co.,[3] with the Mediterranean terminals at Haifa and Tripoli. The current rate of production is approximately 4 million tons per year, and the proved reserves of the field were sufficient to justify the enormous outlay required for the pipeline construction. Against this successful result may be put the fate of the adjacent concession of the British Oil Development Co. in the Mosul area. This company drilled many wells in the extensive area south and north of Mosul, and, although large amounts of oil have been encountered, its quality, owing to high specific gravity, viscosity, and sulfur content, proved such that its export is not an economic possibility. In the early stages much of the finance and material for this work was provided by Italian and German sources, but after many years of discouragement these countries withdrew their support and the further exploration is now being financed by the Iraq Petroleum Co. The total expenditure to date, and so far without economic return, amounts to several million pounds.

During the past year a further concession has been granted by the Iraq Government in the southern part of the country, but as yet its investigation has been confined to the initial geologic and geophysical surveys.

IRAN

Iran ranks fourth among oil-production countries of the world, and its current output is slightly over 10 million tons per annum. The original concession was granted in 1901, but many drilling failures preceded the first success at Masjid-i-Sulaiman in 1908.[4] The pipe line from this field is 120 miles in length and serves a refinery and port at Abadan on the Shatt al Arab. In the northwest, a pipe line connects the fields of Naft-i-Shah to a refinery at Kermanshah which supplies local market requirements. The Haft Kel field was

[3] The control of the Iraq Petroleum Co. is shared between the Anglo-Iranian Oil Co., the Royal Dutch-Shell, American, and French interests.

[4] The history of the development of this concession has already been described to this Society by Sir John (now Lord) Cadman under the title of "Middle East geography in relation to petroleum," Geogr. Journ., vol. 84, pp. 201–214, 1934.

discovered in 1928, and during recent years other discoveries at Gach Saran, White Oil Springs, and Agha Jari have been registered. These new discoveries are required to maintain production and to offset the gradual decline of the older fields. Oil-field discovery in Iran is rendered particularly difficult by the unusually complicated geologic conditions, and a large program of geologic, aerial, and geophysical surveys is continuously required.

Hitherto the oil production of Iran has been confined to these southern regions, but it is well known that oil indications and possibilities exist in the northern Provinces of the country. Five years ago an extensive concession in northern and eastern Iran was acquired by an American company and several years were occupied in preliminary geologic investigations. In the end however it was concluded that, although oil possibilities undoubtedly exist, the expectation of quantity in view of the remoteness of seaboard did not make oil export economically possible at the present time, and the concession was relinquished. During 1939 a Dutch company acquired a concession for minerals and for oil exploration over certain areas in central Iran.

KUWEIT, BAHREIN, ARABIAN COAST, QATAR PENINSULA, AND SOUTHERN ARABIA

Drilling has been carried out at Kuweit for several years, and after an initial failure success was registered in 1937. Further wells are now being drilled, but as yet the extent of the oil field has not been determined. The operating company is under joint British and American control.

An important oil field has been developed by American interests on Bahrein Island, and its current production is approximately 1 million tons per year. The island itself is formed by a single anticline, so that in this case there is no expectation of other similar oil fields within the limits of Bahrein territory. A refinery has been erected on the island and a marine loading terminal serves ocean-going tankers.

Important concessions of considerable size in Saudi Arabia are also held by American interests, and a number of exploration wells have already been drilled in the Hasa Province. So far one oil field has been discovered at Dammam and is now beginning regular production and export. An oil well accidentally caught fire last summer and was prominently reported in our press.

The Petroleum Concessions, Ltd., a subsidiary company of the Iraq Petroleum Co., hold a concession for the Qatar Peninsula, which lies east of the Bahrein Island. Geologic surveys have been in progress for some years and an exploration well is at present being drilled.

Various concessions have been acquired to cover the greater part of southeastern and southern Arabia. Geologic surveys and air reconnaissance flights have been carried out during recent years and are still continuing.

AFGHANISTAN

An oil concession of 240,000 square miles in extent was acquired by American interests in 1934, and extensive geologic surveys were carried out during the following years. A number of oil indications are known, particularly in the northern part of the country, but it was concluded that, though oil fields might be possible, their size was not likely to be sufficient to justify the expense of pipe-line development to the Arabian Sea coast. The local market is also not large enough to justify, for its own sake alone, the large expenditure necessary for exploration drilling. The concession was relinquished in 1938.

ASIATIC U. S. S. R.

Developed oil fields of importance in Asiatic U. S. S. R. are confined at present to three regions, the coastal zone of the Caspian Sea south of Krasnovodsk and including Cheleken Island, the Ferghana Valley in Kirgizia, and Sakhalin. The last named produces about 400,000 tons per year, and Japanese companies participate in the development. Exploration is being actively carried out in various parts of the immense territory of Asiatic Russia and many new discoveries must be anticipated. The Ferghana Valley, being the center of the cotton-growing belt, with silk and mineral industries in addition, has a large local consumption which it is expected will be completely supplied from local sources within a few years. Some small fields, though of low-grade oil, have also been reported in Tajikistan close to the Afghanistan border. The surroundings of Lake Baikal are now being investigated, and theoretically oil fields are possible throughout extensive areas of Siberia. Transport difficulties will, however, handicap any early development of prospects in remote areas. References should also be made to a small producing well in the Taimir Peninsula within the Arctic Circle.

The bulk of both present and past Russian production has come from the European side, but the possible future resources for both European and Asiatic U. S. S. R. are immense. Garfias (see p. 235) has given the proved reserves as 700 million tons, but Gubkin has published estimates far in excess of this. He gives a possible total, i. e., proved plus possible, of 6,376 million tons, and while this may be overoptimistic there is no question of the importance for the future of the oil reserves of the U. S. S. R.

INDIA AND BURMA

Oil production from India is confined to the Potwar Basin area near Rawalpindi, where there are two small producing fields—Khaur and Dhulian—both operated by the Attock Oil Co., and in Upper Assam, where the Assam Oil Co., a subsidiary of the Burmah Oil Co., has a small field at Digboi. In both these areas exploration work has been active for many years, and many other exploration wells have been drilled, but hitherto without further success.

During the past 2 years investigations into oil possibilities have been carried over larger areas, both in northeastern and northwestern India, but no deep drilling has as yet been undertaken. Both British and American companies have acquired exploration licenses. The areas with theoretical, though very speculative, possibilities lie partly in the vast alluvial plains and partly in the foothills. In the former, exploration has involved extensive geophysical work on the part of the operating companies, and in this connection the geodetic work of the survey of India has been of great assistance. Geologic surveys, assisted by aerial mapping, are being carried out in the foothill regions in areas where sufficient outcrops exist to make surface geology possible.

The oil production of Burma is drawn from three principal fields and, in spite of a considerable program of exploration drilling carried on for many years, no recent addition of importance to known reserves has been made. Exploration work, however, is being actively pursued in spite of all discouragements. The possibility of employing geophysical methods in alluvium-covered areas now makes oil exploration practicable in areas which some years ago would have been completely disregarded.

DUTCH EAST INDIES, BORNEO, AND SARAWAK

Oil production from these islands amounted to 8,194,000 tons in 1938, which was drawn from a large number of individual fields. Most of the existing fields are already in an advanced state of decline, but new discoveries offsetting this are being made from year to year and exploration work is being actively pursued.

DUTCH NEW GUINEA, PAPUA, AND MANDATED NEW GUINEA

An extensive concession in Dutch New Guinea is being explored by a company in which American, British, and Dutch interests are represented. A wide aerial survey was carried out at an early stage, and the surface geologic mapping has been greatly assisted by photogeologic interpretation from the aerial photographs. Geologic and

geophysical surveys followed and the exploration drilling stage is now commencing. Up to the beginning of this year about 1½ million pounds is reported to have been spent on this concession.

A number of oil indications are known in Papua and New Guinea and led to an investigation and exploration drilling program in the war years of 1914–18 and subsequently. The results, however, were uniformly disappointing, partly owing to technical and drilling difficulties, and no work was carried out for a number of years. Following recent changes in petroleum legislation on the part of the Australian Government, a fresh attack on the possibilities has recently been commenced and considerable concessions have been acquired by American, British, and Australian companies. I have already mentioned that the Shell Company have abandoned their interest in another area in Papua, after surveys involving an expenditure of over £400,000 had been carried out. The other concessions are now being actively explored and the drilling phase will soon be reached.

JAPAN

Japan, including Taiwan, produced 344,000 tons of oil in 1938. For national reasons of self-sufficiency Japan has been making strenuous efforts to increase her indigenous production for many years, but new discoveries and deeper oil horizons in existing fields have not done much more than offset the decline of the older fields. In 1937 a well was drilled to a depth of 11,502 feet at Kinsin in Taiwan, and several oil sands are recorded below 10,000 feet.

CONCLUSION

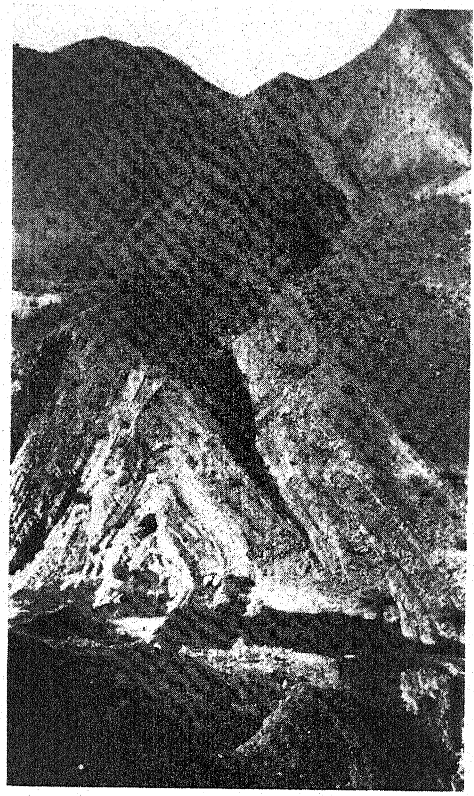
In the foregoing pages I have attempted to analyze the underlying factors governing the present-day search for additional oil reserves throughout the world, and particularly in Asia. The United States has supplied 64 percent of the total oil production of the world up to date and is still producing 61 percent. She has at present a potential output considerably in excess of market demand, and restrictions on production have been imposed in most of the individual States. It is expected, however, that this is a passing phase as, with more and more fields falling into decline, more and more new discoveries are required to offset this cumulative factor, and it is unlikely that the discovery rate of the past two decades will be repeated. The proved reserves of the United States have been estimated at 12 years' supply at the present rate, but new discoveries can be expected to extend this to 20 or 30 years, or perhaps even longer. A decline in total production from the great oil fields of the States is however in sight within a measurable number of years, and a realization of this

fact is responsible for the recent intensification by American interests of the search for oil supplies elsewhere in the world, knowing that 5 or 10 years are required to explore and develop a foreign concession to the point of commencing export. Exploration is particularly active in South America and Asia.

Asia is at present producing 9.4 percent of the total world supply, but without question this proportion will increase substantially in future years. British and British-Dutch companies have been active in oil exploration in Asia for many years and have many notable discoveries to their credit. Recently, however, the search has been considerably intensified and American interests have entered the field on a much larger scale than hitherto.

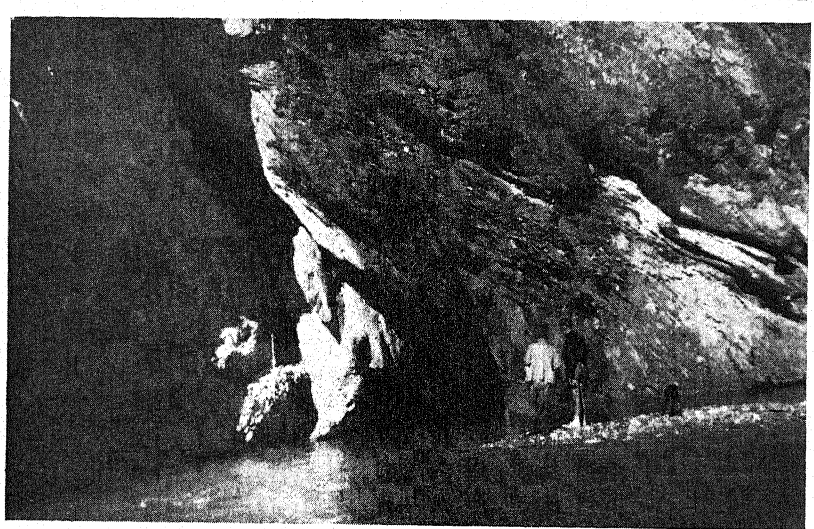
The geographic importance of oil-field discovery and development in Asiatic countries does not require emphasis. The necessary preliminaries of aerial, geologic, and geophysical surveys enormously enhance our scientific knowledge of hitherto little-known parts of the world, and the subsequent opening up of inaccessible regions by oil-field development can bring about far-reaching sociological changes by the introduction of money, employment, and quick means of communication by road and by air. The search for oil is playing an ever-increasing part in the westernization of many parts of the East.

Asia, with 55 percent of the world's population, has less than 5 percent of its oil consumption, but this is a changing circumstance. Hitherto most of the oil fields in Asia have been developed for export and only areas adjacent to coast line, or oil fields of a size to justify the large expense of pipe lines to seaboard, have been developed. As mechanization progresses and as more and more motor roads are built and used, the internal market becomes increasingly important and will lead to oil-field development for its own sake alone. We are now ceasing to gape at the superficial changes effected by the impact of West upon East—the tribal shaikh driving across the desert in his expensive American car, Arabs in Jidda listening to broadcasts from European wireless stations, Iranian cities cut across by boulevards modeled on European pattern, and countless such familiar incongruities that demonstrate the intrusion of Western behavior into Asia. The West has not only produced the pattern of modern life but, in countries where oil royalties form a substantial part of the yearly budget, the wherewithal to copy it. The movement is gradual, but now inexorable. How far habits of life will change habits of mind is a matter for conjecture . . . but with this thought I seem to be diverging too far from my geologic analysis of the search for oil.



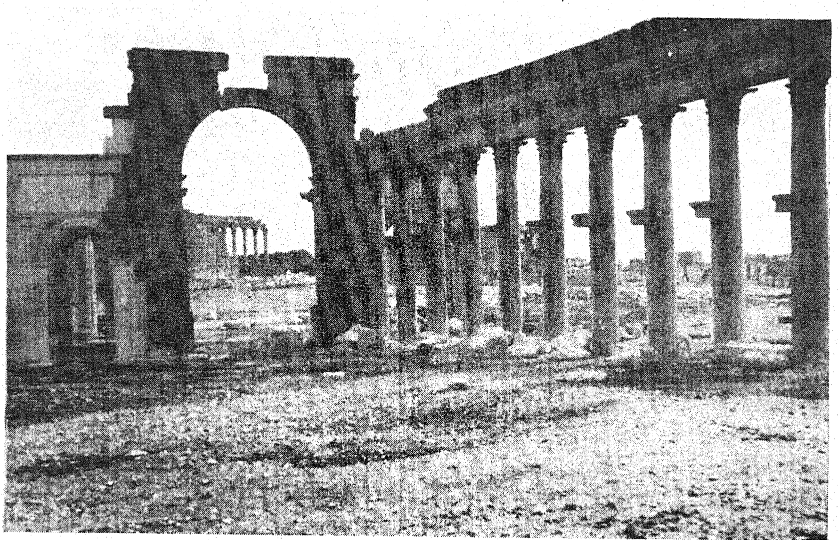
1. FAULTED ANTICLINAL AXIS, AGHA JARI.

2. ANTICLINAL AXIS, SOUTH IRAN.



1. GEOLOGISTS EXAMINING OIL-IMPREGNATED ROCKS.

2. A SEEPAGE OF THICK OIL WITH GAS BUBBLING IN THE CENTER OF THE POOL AT HIT, IRAQ.



1. PALMYRA, IN THE SYRIAN DESERT. AN EXPLORATION WELL IS BEING DRILLED NOT FAR FROM HERE.

2. AN EXPLORATION WELL IN SOUTH IRAN.

LOOKING ACROSS THE BULOLO VALLEY AT WAU.

Township of Wau in the foreground, with airdrome (A) and the Bulolo River (B) in the background. The scarp behind is composed of Kaindi series with granitic intrusions. The low, grassy dip-slopes near the Bulolo River on the right are Otibanda series. The valley is a young Tertiary downwarp. (A. P. C. Photo.)

PERSPECTIVES IN EVOLUTION[1]

By James Ritchie, M. A., D. Sc.
President of the Zoology Section, British Association for the Advancement of Science

"All useless science is an empty boast," Shakespeare is alleged to have said, but he lived before that pernicious cleavage had been made between pure science and economic science, which suggests that the latter is a gold-digger while the former excavates only knowledge. And while we are strongly in favor of those lines of scientific endeavor which make their first purpose an attack upon the evils that man and his possessions fall heir to in the course of nature, and which aim at easing the human struggle for existence, there are questions of no immediate practical moment to which the inquiring spirit of humanity demands an answer. I do not think Shakespeare would have called these recurrent problems "useless science," for the mind of man requires satisfaction as well as his material need.

It is characteristic of the modern evolution of scientific method that as the zoologist becomes more and more engrossed in a particular problem within the restricted field in which he specializes, his opportunities recede of gaging the effect of discoveries in other fields upon the general problems of life. Even if he desires to keep in touch with such inquiries, whom is he to follow? Juvenal declared that "Nature never says one thing and Science another," and while that is true of science in the abstract, it can scarcely be true of the purveyors of exact knowledge so-called, the scientists, for they speak with many and often discordant tongues.

There is another reason which suggests that a restatement of some of the great problems may be appropriate on this occasion. Since the British Association last met in Dundee, in 1912, and Sir Peter Chalmers Mitchell addressed this Section upon the need for furthering the protection of animals whose existence was threatened by the advance of civilization, great progress has been made in many directions. Much has been done, for example, for the cause so com-

[1] Address to Section D, Zoology, of the British Association for the Advancement of Science, Dundee meeting, 1939. Reprinted, slightly revised, by permission of the Association, from The Advancement of Science, new quarterly series No. 1, October 1939.

petently advocated by Sir Peter Mitchell; but in no direction has there been more striking endeavor than in the testing of old and once widely accepted theories by the touchstone of detailed analysis and experiment. That is a distinctive feature of post-war zoology, and its milestone was erected by Alfred J. Lotka in 1925. It has had a salutary effect upon theorizing, for "Experience is the greatest baffler of speculation," but if speculation gains in precision through running this new gauntlet, it must not be forgotten that experiment also gains from the association: "Knowledge directeth practice and practice increaseth knowledge."

So, since I think that truth may lie between analysis of long-range views and synthesis of detailed discoveries, I take this opportunity of laying before you some ideas concerning life and evolution.

THE SECRET OF LIFE

There was a Scottish politician and philosopher, a former Duke of Argyll, who, among many sayings that are forgotten, took pleasure in reminding the world that "Science has cast no light on the ultimate nature of life." He stood for the rather facile vitalism which loves a mystery and regards the probings of science as bringing knowledge only with the accompaniment of disillusionment. In the opposite camp is the mechanist, in whose view the processes of life are to be explained solely and completely by the concepts of chemistry and physics. The two aspects, the mechanistic and the vitalistic views, have been canvassed so thoroughly that it would be profitless to trace the controversy again, if indeed the controversy has any real antithesis and does not represent simply two facets of one common truth. But it is legitimate to ask what recent years have contributed toward the solving of the secret of life.

The outstanding fact which strikes the observer is that the extreme positions, physical and biological, have become untenable, and that concessions are being made by both sides. The vitalist's vitality is being whittled down, animation is being put into the mechanist's machine. Sir James Jeans (1933) from the physicist's point of view has stated that living things in some way possess the power of evading the established physical order of disorganization, and in so doing he has conceded more than most biologists demand. When, in his plea at the Cambridge meeting of this Association, in 1938, for the inclusion of probability in the scheme of physical conceptions, Dr. C. G. Darwin stated that the trouble about forecasting the future from our knowledge of the present was the impossibility of knowing the present, he was formulating precisely that difficulty of knowing the conditions of life activity which besets the biological experimenter in endeavor-

ing to interpret life axiomatically, a difficulty which appears to be insurmountable. A common ground, even if it be largely a common ground of uncertainty and cautiousness, is being approached by the schools of physics and biology.

Broadly it may be said that the efforts of recent years have done much to reduce the mystery of life. An elusive quality remains, but the elusive quality is retreating within its shell, and its shell becomes smaller and smaller, just as the corresponding physical mystery has been driven from stronghold to diminishing stronghold, from molecule to atom, from atom to proton and electron with the irreducible quantum of activity. Such advances as have been made in the interpretation of life have been due to the application of physical and chemical methods and concepts.

There have been theoretical interpretations, working hypotheses founded rather on analogy than deduced from direct observation, like the oscillatory theory of Lakhovsky (1929), who regards the cell as an electromagnetic resonator, active in absorbing and emitting radiations of very high frequency. Life, in his view, is the dynamic equilibrium between such cells, the harmony of innumerable radiations reacting upon each other. Or the vortex theory of Lartigue (1929) who, endeavoring to extend to the domain of life the laws of eddies, comes to the conclusion that the living organism is not an ordinary thermal machine, since it works at a temperature practically constant, nor an ordinary electrical machine, since it works at a practically constant potential, nor an ordinary chemical machine, since there is no sufficient explanation of the activity of its chemical processes taking place almost at neutrality. Instead he looks upon the living cell as a thermoelectrical unit based upon an etherial vortex, and the appearance of life upon the earth as the appearance of such a vortex activated by a triple movement of centripetal precipitation, of centrifugal diffusion, and of ellipsoidal or cylindrical rotation, and sufficiently persistent to construct a body by sweeping along matter in its train and thereafter to engender other vortices specifically like itself.

These are tenuous speculations at best. It is to the lasting credit of the department of zoology in this university college of Dundee that it gave to the world a reasoned dynamical interpretation of organisms which, working on solid ground, revealed the physical basis of much that had been regarded as manifestations of the peculiar properties of life. His presidential address to our Section of the British Association at Portsmouth in 1911 showed that Sir D'Arcy Thompson had already been turning over in his mind the adequacy of the forces of surface tension, elasticity, and pressure to explain a multitude of the phenomena illustrated in the appearances of living things; but the publication of Growth and Form in 1917

exposed, with a wealth of detail that set the subject in a new light, the far-reaching influences of physical forces on the growth and ultimate conformation of organisms and the parts of organisms.

While the structures, the "things seen" in the architecture of animate nature, have been yielding their secrets to such physical analysis, the activities of living stuff, far less easy to comprehend, and yet more intimately part of life than the material plasms through which they are expressed, have also been giving way to the skilled attacks of the physicist and chemist. Here investigation has naturally been concentrated upon the unit of organization, the cell, and it has shown that just as the cell boundary is determined by physical forces, of surface tension, so activities of the living cell membranes, which form its boundary, also fall into line, so far as analysis goes, with physicochemical laws. Thus the living cell, of plant or animal, acts as an osmotic system, as de Vries showed long ago with the leaf cells of *Tradescantia* and as has been shown for many animal cells such as mammalian red blood cells and leucocytes, spermatozoa, muscle cells of frogs, and egg cells of echinoderms. Moreover, the adjustment of forces within and without living cells has been found to be in accordance with the thermodynamical balance known as the "Donnan equilibrium" or "membrane equilibrium," which interprets the relationship between solvents separated by a membrane, on one side of which is a nondiffusible ion or molecule. (For a summary of the biological aspect, see Dixit, 1938.) Part of the activity of a cell, at any rate, is amenable to purely physicochemical explanation.

Further understanding of the activities of the cell as well as practical benefits to humanity have followed upon the enzyme discoveries of recent years. I would remind you of only one example, that the digestive enzyme of the papaya plant, papain, is now used in America by the ton in making tough meat tender. As Balls (1938) put it, in an address to the Washington Academy of Science, " we should probably all be surprised to know the exact number of years of beef life that is taken out of the steaks of America by means of papain"; though I have a strong suspicion that knowledge of this great discovery has not yet penetrated to the roast beef of old England. As regards cell activity the enzymes act as catalysts speeding up chemical reactions; without enzymes cell processes would "proceed so slowly that the cell would die waiting for food to be digested or oxygen to become available" (Balls, 1938).

From these few examples it is patent that much that was mysterious about life has disappeared or is disappearing before the persistent inquiries of the physicist and chemist. Life processes of the physiological order are ruled and guided by the selfsame laws which regulate action in the nonliving world.

But it is just as obvious that none of these interpretations reach the secret spring of life itself. The physical explanation of the architecture of animals must assume the power of the living thing to react and mould itself to the forces that play upon it. Osmotic reactions do not explain wholly the exchange between cells and their surroundings, as Gross (1939) found in the diatom *Ditylum brightwelli*, in which his experiments led him to postulate a vital activity of the cells involving perhaps the secretion of water, a supposition since confirmed by Bhatia (1940) working with Gross in the department of zoology of Edinburgh University. The Donnan equilibrium, which interprets a condition of thermodynamical balance, meets the case of a living cell only when the cell activity is at its lowest; and the more active, that is the more alive, a cell is the less does the Donnan theory become applicable.

No known law can account for the curious way in which substances are sorted out and grouped on opposite sides of living membrane. It has been shown to be widely true that on one side of living protoplasm acid is produced (as in the stomach) together with a higher concentration of potassium, ammonium, phosphate and, if they be introduced into the blood, basic dyes; whereas on the other side occurs sodium (on the blood side of the stomach) associated with the production of alkaline substances and the assembling of introduced acid dyes. Such anomalous grouping is repeated in plant cells which produce acid and potassium concentrate on the inner side and, on the other side of a protoplasmic film only one-hundredth of a millimeter thick, alkali and calcium concentrate. As Keller (1938), in his survey of these odd contrasting groups, sums up the situation: "We cannot explain how a unipolar living electrode is able to produce or concentrate on one side acid and the potassium group, on the other alkali and the sodium group, but we have to accept this fact as generally observed in all animal and plant cells as long as the electric potentials of the cells are normal and the normal oxygen supply is at the disposal of the cells."

Enzymes may be necessary for the complete activity of a cell, but though it may hasten a chemical reaction no catalyst can set a reaction in motion; in the case of the cell that appears to be the prerogative of "life."

Minute analysis still stops short of the secret of life.

THE QUALITY OF LIFE IN PERSPECTIVE

Let us turn, then, from the minute analysis of the unit of life, which in recent years has done so much to reduce the mystery of life, without however reaching the kernel of the mystery, to see what suggestion may arise from another point of view, a perspective of evolutionary processes.

It is difficult for us, overwhelmed by the complexity of evolution, to single out those features which are most distinctive of life, but suppose we hand the problem over to reasonable beings of our imagination, who, coming from a world such as ours, but on which life has never existed, view for the first time the earth. We may imagine them to be physicists or chemists or even mathematicians, for obviously no biologist could come from a lifeless world!

Among many wonders, two things would strike these visitors as outstandingly peculiar. The first concerns the structure of the earth's crust. In it occur unlikely accumulations which would have no counterpart in a lifeless world. Average sea water contains only 0.12 part of calcium carbonate per thousand, yet some 48 millions of square miles of the ocean floor are covered with a deep deposit of calcareous ooze containing calcium carbonate up to 90 percent. The coral islands of modern seas, the chalk and limestone formations which represent relics of the oceans of geologic times and which make up a very considerable part of the solid crust upon which we live, have been similarly abstracted and assembled by living animals from sea water. Soluble silica occurs in very minute quantities in the ocean, never exceeding 1.5 parts per million, yet in our present-day oceans plants have assembled from such a dilution, 10 millions of square miles of diatom ooze, and radiolarian ooze accounts for another 2 millions of square miles of siliceous accumulations.

From the atmosphere, as well as from the ocean, unlikely aggregates have been sorted out. The average proportion of carbon dioxide in the lower atmosphere is about 3 parts per 10,000, yet the superficial deposits of peat and the deeper formations of coal, oil shale, and the natural petroleum produced from them, consist essentially of carbon sorted out by plants from that tenuous store. The carbon dioxide, dispersed and inert, in 16,125,000 cubic yards of air is gathered and made potentially efficient by a single tree of some 5 tons dry weight.

To us these aggregates have lost all sense of wonder, but to our physicists from a lifeless world they must seem as unbelievable as the giraffe to the youngster at the zoo, for they controvert one of the established laws of physical order, that, left to themselves, units of matter in a gas or a solution move toward their maximum dispersal. The normal physical course of dispersal in the cases I have mentioned has been replaced by assortment and aggregation, and the agent of the reversal has been the living organism.

The second stumbling-block over which our visitors would trip in their prospect of the earth is supplied by the history of living things themselves. The life history of any multicellular organism is a development, that is a selection and reassortment of materials

in such a way that the organism beginning as a fertilized ovum, already complex in a morphological and physicochemical sense, becomes still more complex. The history of life upon earth in the broadest sense is also an evolution from more simple to more complex. It might be said that even in the lifeless world from which our visitors came, inorganic things showed an evolution from more simple to more complex; that, for example, an ancient range of mountains, with its peaks and valleys, its corries and its precipices, is much more complex than the simple fold of the anticline which was its beginning. But that is a complexity due to disintegration, and is entirely in consonance with the physical law of randomness which would assert that in the long run the hills will be deposited in the valleys so that both will attain a common level beyond which leveling can go no further. But the complexity of the evolution of life is no disintegration; on the contrary its characteristic is integration, a building up associated with an increase in the orderly arrangement of particles, and not, at any rate as we focus our eyes upon the products of evolution, an increase of randomness.

Further, if our visitors were fortunate enough to have a biologist as their mundane guide, he would give a final shock to their physical concepts by informing them that we believe protoplasm, the essential living matter, to have risen from a fortuitous concourse of atoms, and such an event, where physical law demands dispersal and randomness, is exceedingly improbable, though nothing is impossible. In brief, place before your physicist who has no knowledge of life, the series atoms, protoplasm, unicellular organism, metazoan, and ask him which came first; and he will swear by all the laws of inorganic nature and statistical probability that the metazoan must have started the chain and must have evolved or disintegrated into the unicellular organism, and that into primeval protoplasm, which must finally have dissociated into its constituent atoms. But we know that the reverse is the true sequence, the reverse of physical probability.

Is this then a fundamental secret of life, that it reverses the physical law of dissipation or increasing randomness? There has been long argument "about it and about," but to take recent expressions of opinion, that is the view taken by Sir James Jeans, who frankly states that "what we describe as life succeeds in evading it [i. e. the second law of thermodynamics or the law of increasing entropy or randomness] in varying degree" (1933, p. 276). Other writers going further see in the paradox "the intervention and continually active interference of a guiding force which, in the case of life, lifts it into a higher plane of existence where it is not subject to the laws of entropy" (H. V. Gill, 1933). The opposing

point of view is that the processes of life offer no obvious contradiction to the second law, since if all other related and simultaneous actions be taken into account the total effect will be an increase of entropy. (See, for example, Donnan, 1934.) That may be so, but it is an unproved suggestion; and the phenomena of life and its evolution are so complex that if the resolution in terms of physical law of "all other related and simultaneous actions" has to be pushed from item to item until, as it were, the universe is involved before a balance can be struck, then entropy has little immediate significance for life activity.

It comes to this, that in practice the second law of thermodynamics, so well established for physical happenings, cannot be satisfactorily applied to living processes. And that while no one would deny that living things in the long run and in a universal sense are subject to its demands, and indeed that in their workings they are probably controlled by it, nevertheless organisms appear to be able temporarily to hold up or withstand the physical course of degradation of matter, if they do not actually reverse it.

From this point of view, then, the secret of the living organism, that is its essential difference from nonliving matter, is its power of trading with its environment in such a way that it can build up its body-stores of high potential energy from materials of lower potential.

So we are led to two conclusions. The origin of life must be sought in a concourse of atoms, improbable as that may seem, which traded with an inorganic environment. The first organism is unlikely to have been of the nature of a virus, although viruses have been suggested as the nearest approach we know to a primeval existence, for whether a virus be alive or be a nonliving protein molecule, it multiplies by acting upon the organic materials of its host, and that presupposes the existence of other living things. It is unlikely that the first organism was of the nature of a green plant, for chlorophyll is a highly organized stuff, and although some form of energy must have been utilized in the building up of the first organic molecules, we do not know whether it was the energy of sunlight, as in photosynthesis, or of a chemical reaction like the chemosynthesis which characterizes the life processes of certain sulfur, iron, and nitrifying bacteria. But even bacteria have their organization and it may be supposed that before them there came into being precellular diffuse stuffs, not yet recognizable as definite organisms, whose one outstanding character was their power of using for their own aggrandizement some form of energy about them and external to them.

A second conclusion follows upon our analysis. Phenomena of life elude treatment by the laws of thermodynamics, not necessarily because living matter does not obey these laws, but because the unknown conditioning of working organisms is too complex to yield to analysis applicable to inorganic states. Nor does it seem likely, since livingness exists within a very limited range of temperature and is readily extinguished by interferences, that it can ever be subjected to the sort of analysis which has led to the interpretation of the constitution of physical matter. It seems logical therefore to take as axiomatic the existence of life, not as a vital force which animates something different, namely matter, but as the activity of an atomic combination, the very activity of which renders it unanalyzable by the standard methods of the physicist and chemist. Thus, as one of the greatest of living physicists, Niels Bohr, has pointed out, the biologist would accept for the living world a position analogous to that accepted by the physicist for the non-living. "The existence of life must be considered as an elementary fact that cannot be explained, but must be taken as a starting point in biology, as in a similar way the quantum of action, which appears as an irrational element from the point of view of mechanical physics, taken together with the existence of the elementary particles, forms the foundation of atomic physics" (Bohr, 1933, p. 457).

And the biologist, admitting "life," may build up a whole body of biological theory, as distinctive and peculiarly his own, and as logical in the logic of probability which Professor Darwin advocates, as are the theories of the physicist or the chemist in their own limited fields.

LENGTHENING OF LIFE PERSPECTIVE

There is another notable development of this century which must affect evolutionary thought, the expanding idea of the time during which the earth and life upon the earth have been in existence. Broadly three methods of making the estimation have been canvassed—physical, geological, and biological; but from the fundamental uncertainty which attaches to conditions of life, it may be assumed that biological methods are bound to be problematical and unsatisfactory. To illustrate the enormous change in outlook which has taken place let me mention a few of the estimates.

An early estimate was biological, founded upon the genealogies of the Book of Genesis. It used to be familiar in the reference column of the Bibles of a past generation such as Bagster's Polyglot Bible, where the creation is set down precisely at 4004 B. C. In the eighteenth century, Buffon, a far-seeing naturalist who had views upon evolution ahead of his time, put the matter to the test of experiment. Recognizing in the earth a cooling body, he measured

the rate of cooling of cast-iron balls, and from the results boldly stated that the six days of Biblical creation were "periods" to be extended as the facts required, and that the age of the earth was actually some 75,000 years.

Scotland took a prominent part in the many discussions of the subject which took place in the nineteenth century. It was Lord Kelvin who, from the secular cooling of the earth, concluded that the globe must have consolidated not less than 20 millions of years ago, and finally suggested limits between 20 and 40 millions of years; and it was Professor Tait who reduced that estimate to from 10 to 15 millions of years. The geologic view was expounded by Sir Archibald Geikie at meetings of the British Association at Dover in 1899 and at Edinburgh in 1892, and he summed up for an interval of "probably not much less than 100 million years since the earliest forms of life appeared upon the earth and the oldest stratified rocks began to be laid down."

From these earlier discussions it would appear that a psychological element entered into the final estimates, as if the calculators drew back aghast at the possibility of the enormous age of the earth at which their estimates hinted. Thus almost all tended in their final summing toward the minimum of their scales, and little is heard of the other extreme—Lord Kelvin's independent maxima, reached by different methods, of 1,000, 400, and 500 million years, or Geikie's 400 million years—although these came much nearer to the modern estimate.

The effect upon the biologist of the varying estimates, of their uncertainty and the adverse criticism to which they were subjected, was such that he simply ignored them. Thirty years ago it was the worst possible form, zoologically, to mention them. But now, thanks to a consensus of opinion that admits credibility to estimates based upon the break-up of radioactive minerals in the rocks, the reputed ages of the geologic formations are creeping, somewhat apologetically, into the biological textbooks. They have passed through the textbook needle's eye; that is a sign for anyone to read.

Some of you will remember the joint discussion, shared in by the Zoology Section, at the meeting of the British Association in Edinburgh in 1921, when Lord Rayleigh summarized the physical evidence from the break-down products of uranium. Since then the methods of estimation and calculation have been refined, but the results of several methods appear to be in substantial agreement. Thus the beginning of the Cambrian formations, with their well-preserved fossils, were laid down probably about 500 million years ago; below the Cambrian are formations with relatively few and mostly ill-defined fossils, which carry the relics of life back some

800 million years, and stretching away beyond that we must imagine a period when life was evolving in its most primitive forms, of which no trace remains or could remain. We may say that life has existed upon the earth for perhaps 1,200 millions of years; and then to complete the picture that the birth of the earth, and as the new cosmology seems to indicate, perhaps also at the same time the stupendous birth of sun and stars, took place about 2,000 million years ago.

STABILITY OF ORGANISM AND SLOWNESS OF EVOLUTION

This amazing extension of the time concept of life emphasizes anew some of the striking features of evolution. We are accustomed to lay stress on the variation of living things, upon which evolution depends, but surely more remarkable is the stability of living organisms, which retain their own characters in spite of changes in the environment, and whose germ cells pass these characters unaltered through countless generations. The edible cockle (*Cardium edule*) has retained its specific characters for 2 million years or more; its genus, in a wide sense, lived 160 million years ago in the Trias. The crinoid genus *Antedon* which flourishes in our own seas antedated that old bird *Archaeopteryx* in the Jurassic period, 140 million years ago. It is surprising enough to realize that genera of foraminifera, like *Nodosaria* (Silurian) and *Saccammina* (Ordovician), still abundant in our oceans, have retained their generic characters for about 300 million years. But they are relatively simple organisms; it is still more astonishing to think that contemporaneous with them or before them lived modern genera (again in the wide sense) of more highly organized brachipods, like *Lingula* (Ordovician), and *Crania* (Ordovician), and that these have experienced the geologic upheavals and secular changes since Paleozoic times without turning a hair, or in the revised version, without the shift of a gene upon a chromosome.

It is in agreement with that stability of organisms that we must conceive of evolution as a process of extreme slowness, as if living things are loath to change, and ultimately change only under the direct compulsion of circumstances. Of that slow progress in its minor phases the new chronology gives us a measure. One or two well-known examples will illustrate the point. Matthew (1914) and Osborn (1917), each in his day, suggested a time scale for the evolution of the modern horse (*Equus*) from its precursors of Eocene times. But the newer data bearing upon geologic ages should contribute further precision to a fresh estimate. Accepting, then, the data from helium and lead methods of time estimation as given by Holmes (1937), we find that the whole gamut of changes which modified the four-toed forelimb of *Eohippus* into the single toe of *Equus*, from Lower Eocene to Upper Pliocene, occupied about 57 million years. It took some 17

million years to reduce the four effective digits of *Eohippus* (Lower Eocene) to three in *Mesohippus* (Lower Oligocene), and 22 million more to raise the two lateral digits clear of the ground (in *Merychippus*, Middle Miocene). The penultimate stage of reducing the ineffective side digit to vestigial splints (in *Plesippus*, Upper Pliocene) occupied some 16 million years, and the gradual reduction of these vestiges to the condition seen in the modern horse (*Equus*, Upper Pliocene) probably took about another 2 million more.

Time evolution in the series of invertebrate animals may be illustrated from A. W. Rowe's well-known study (1899) of the unbroken gradation of variations in the fossil sea urchin *Micraster*. The Cretaceous period occupied in all about 40 million years. A rough proportional estimation would suggest that the evolution of the foundation species of the series *Micraster cor-bovis* into *M. cortestudinarium* (i. e., from the *Terebratula gracilis* zone to *Holaster planus* zone) took about 1 million years, while the further changes which eventually produced *Micraster cor-anguinum* occupied an additional 1½ million years.

From another standpoint a view may be gained of the race of evolution in recent times. The American scientist, O. P. Hay, stated in 1928 that "a learned writer on mammals tells me that he doubts that a single new species has developed since the first interglacial stage." But the suggestion is incorrect. In the outer islands of Scotland there are recognized several species which are distinctive of the islands, such as the Islay shrew (*Sorex granti*), the Orkney vole (*Microtus orcadensis*), the Mull bank vole (*Evotomys alstoni*), the Hebridean field mouse (*Apodemus hebridensis*), or its relatives in Fair Isle (*A. fridariensis*) and in St. Kilda (*A. hirtensis*), and the St. Kilda house mouse (*Mus muralis*)—to take examples from several different genera. We need not discuss the special characters of these species, it is enough that they are recognizable and are regarded as distinctive by the specialists best qualified to judge.

Now a time limit is set to the evolution of these species. Scotland itself and its islands were overwhelmed with glaciers during the Ice Age, life was extinguished, and it was only after the ice had passed away and the land had subsequently become clothed with vegetation that the country became fit for even shrews and rodents to live in. The mainland of Scotland was stocked by migration from the continent of Europe, the islands presumably from the mainland, and since that time the new species of the islands have branched off from their mainland ancestors. All this must have happened in a period subsequent to the last great glaciation. Penck reckons the Bühl stadium of postglacial time in Northern Europe at about 20,000 years B. C., and that probably indicates the maximum of time which may be allowed for the evolution of the Scottish island species.

It is natural that the degree of change involved in the transformation of those species cannot be compared with the generic changes in the horse series, reckoned in their millions of years; and yet it is plain that the comparatively slight changes shown by the endemic species of the Scottish mainland and the islands, as well as many less marked changes seen in the geographical races of Scottish birds and mammals, while of postglacial origin, have had available for their development a range of years far exceeding the span of human observation or tradition.

If this time factor is a necessary element in the evolution and establishment of species in nature, doubt is thrown upon the validity of arguments concerning evolution based upon laboratory experiments in which intensification of means produces rapid change. There is no reason why the reaction of an organism under such exaggerated stimuli should be the same as that produced by minimal influences of the same nature over an exceedingly long time. Even in inorganic nature the reaction of inanimate environment may differ according to the time element. A new stream makes its way along fissures and weaknesses in the substratum on which it flows, and this first course may determine the meanderings of the stream through long ages. But concentrate the flow of a year or several years in a cloudburst which falls at the source of the stream, and the track made by the torrent, cutting across obstacles, may bear no resemblance to the age-worn course, except that it runs downhill. The sensitive organism delicately adjusted to a particular environment is less likely than inorganic environment to give a "natural" answer under concentrated compulsion.

ADVENT OF MAN AND EVOLUTION

The lengthening of the time perspective of life upon the earth adds new insignificance to the span of man's tenancy of the world and new impressiveness to the part he has played as an agent in evolutionary processes. Man of our own genus, beginning in the early Pleistocene period, has probably less than a million years behind him, but the species of man now dominant in the world (*Homo sapiens*) appeared only at the close of the Würm glacial stage, no longer than 25,000 to 40,000 years ago. Yet even this relatively short space of time exceeds man's span as an effective agent in world change, for in spite of the arts he developed in early postglacial times he remained practically submerged in the fauna, having little more influence upon his environment than the beasts with which he shared it.

> Man walked with beast, joint tenant of the shade;
> The same his table, and the same his bed.
>
> —POPE.

It was Neolithic man who set the ball a-rolling through his outstanding achievements in domesticating wild animals and in developing the cultivation of the soil and growing of crops. For these achievements, apart from laying the foundation of a new era in the progress of civilization, started a series of changes which have profoundly influenced the distribution of life upon the earth. In one direction the safety of flocks and herds demanded the elimination of beasts and birds which threatened them, and in another the need of land for crops and pasturage played havoc with the wild environment and so with the fauna which it sustained and sheltered, although the crops themselves encouraged the multiplication of certain elements in the fauna which became the pests of agriculture.

The Neolithic age, which originated these changes, reached Western Europe only some 8,000 years B. C., though in the East and in the lands of old culture it began several thousands of years earlier. But Neolithic man, although he initiated the most far-reaching changes in plant and animal life, was himself, with his implements of wood and stone and limited powers of offense, ineffective in his interference. Even in a limited area like Scotland, few animals died out during his rule and it would be difficult to bring home to him responsibility for their disappearance. For the effective introduction of man as an agent of evolutionary change we must look to a time more recent. And that time is determined by his increasing efficiency as a cultivator and destroyer, and particularly by the need for food and fire demanded by an increasing population. These influences began to make their mark about the tenth century of our era when several of the interesting members of the primeval fauna of this country had disappeared or were on the verge of extinction, but in the centuries following the sixteenth they commenced a period of pressure, which, increasing in intensity, has transformed the faunas of civilized lands.

It is not an accident that the emergence of man as a major factor in the evolution of faunas coincided with the increased power of destruction presented to him by the invention of gunpowder and guns, and with that extraordinary increase in population which in the last 300 years has multiplied, almost five times over, the numbers of mankind upon the earth (see Pearl, 1937). For this burst of population was itself the accompaniment of intensified agriculture and stock-rearing, of the spread of industries and development of commerce, all of which have had profound repercussions upon aboriginal faunas and floras.

While modern man has existed upon the earth for some 30,000 years, his part as a distinctive agent in the evolution of faunas is limited to a thousand years, and within that span his great trans-

formations are practically confined to the last 300 years. That is a period infinitesimally short compared with the ages during which the aboriginal faunas into which he was launched had been differentiating, redistributing, and establishing themselves in a natural balance. What transformations has he wrought in so short a time? The lengthening perspective of life upon the earth gives new significance to the extent of man's interference.

I do not propose here to examine in detail the magnitude of this new world factor in the evolution of faunas and floras. That is best shown in a limited area which can be intensively studied, and I have elsewhere described with reasonable thoroughness the stages and sum total of this process in Scotland, the recent geologic history of which makes it particularly suited for such an analysis (Ritchie, 1919, 1920, 1923). I may, however, indicate the depth of penetration of this new faunistic factor by pointing out how superficial is the view that regards man merely or mainly as a destroyer. He has indeed deliberately reduced numbers or extirpated animals for his own protection or for that of his flocks and crops, for food and other necessities, for sport, and to satisfy the whims of luxury; and without intention his cultivation of plains and marshes and destruction of primeval forest have destroyed feeding grounds and banished their former tenants. Yet his addition to numbers far outweighs his destruction. Intensive cultivation has added a stock of domestic animals far beyond the bearing capacity of wild country, besides increasing the numbers of wild creatures which also benefit from his crops. Deliberate protection of animals, for sport, for utility, for esthetic reasons, and on account of popular superstition, has also multiplied numbers. Furthermore, apart from numerical changes within the aboriginal faunas, man has changed their qualitative composition by introducing foreign animals deliberately (here we must include domestic animals), and unintentionally through the ramifications of international commerce.

These are simple primary effects of man's interference; secondary and remote consequences are even more impressive in their ultimate issues. In general it may be said that wherever civilization has made itself felt three main faunal changes are noticeable: The largest animals tend to be reduced in numbers and eventually to disappear; smaller creatures, dependent upon cultivation and human habitations, multiply far beyond aboriginal numbers; and the deliberate or accidental spread of "foreign" creatures is creating a degree of cosmopolitanism throughout the world's faunas.

How do these changes brought about by man stand, viewed in the perspective of the long evolution of faunas upon the earth? There are two types of change in progress in the natural assemblage of

animals in any region. There is a constant ebb and flow within the fauna itself, due to local and temporary influences, a swing of the pendulum about a mean, the "balance of life" which is never quite struck. But there is also a faunal drift, revealed in the story of the rocks or in any long vista of faunal history, and this is due to great secular changes, to geologic influences, to modifications of climate, to the insurgence of the forces of life.

Where man's interference is temporary and casual it may be compared to the internal faunal tide, which is of little moment in the long run; but where his interference is persistent in any direction it must be reckoned as sharing with the great secular forces of nature in propelling a fauna upon a path along which there is no return.

Such is the remarkable conclusion to which the long view of man's place as a natural agent brings us—that he has set in motion forces which, in our era and mainly in the last 300 years, have wrought faunal changes which can be compared only with the great secular changes of world evolution. And when the ridiculously short span of his interference is contrasted with the slowness of natural processes, the probability forces itself upon us that in a few more thousand years of man's inheritance of the earth the old order of nature will be superseded in the faunas of the world by a new order of mankind.

MAN IN EVOLUTIONARY PERSPECTIVE

Having thus assigned to man dominance amongst the forces which determine faunal assemblages, let me now endeavor to put him in his place in the long perspective of life and evolution.

Temporarily his past is insignificant, how insignificant it is almost impossible to realize. But let us picture the unimaginable space of time since life began as a 12-hour day, beginning with the first living molecules in an early world at midnight and reaching a climax, as we should say, at the high noon of evolutionary attainment—ourselves. These 12 hours will represent, according to the data I have already referred to, roughly 1,200 million years, each hour 100 million years, each minute rather more than 1½ million years. Our clock must be a 24-hour clock, for we can assume that life and evolution will continue in the future (for the convenience of my diagram, supported by the calculations of the physicists) say as long as life has already existed. Then the long period of indeterminate living things almost unrepresented by fossils would have existed from zero till 7 o'clock; the Paleozoic period, when fishes and amphibia predominated, till about 10 o'clock; the Secondary period with its predominant reptiles till about 11:15; and the great devel-

opment of birds and mammals in the Tertiary period would be confined to less than three-quarters of an hour before midday. Now in this procession primitive man makes his appearance with the Ice Age at less than a minute to noon, and man of our own species (*Homo sapiens*) less than a second and a half ago. On our time scale all the developments of historic man, all the wonderful achievements of civilization, all the new order of mankind in nature has been crowded into less than one-tenth of a second.

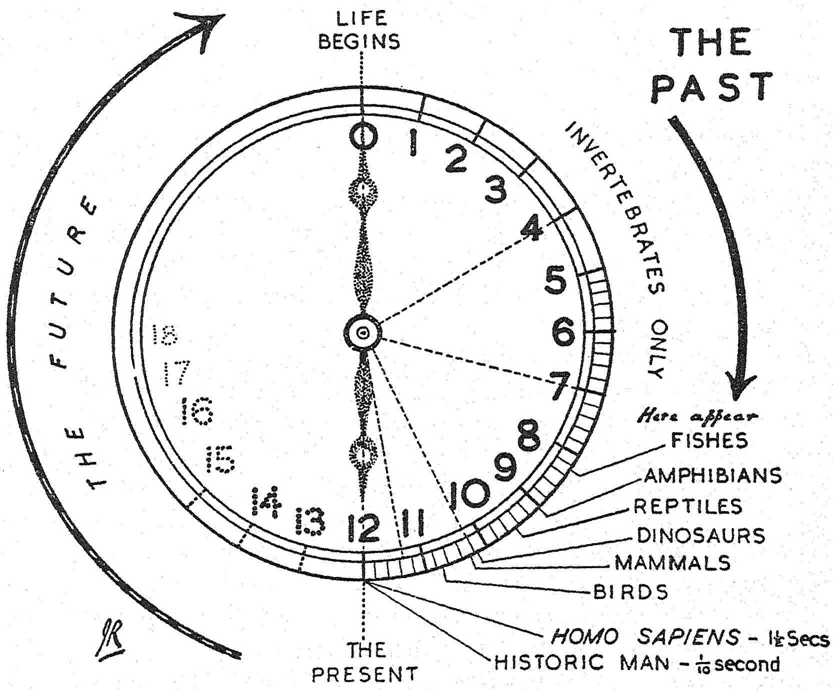


FIGURE 1.—The evolution clock, illustrating the relative length of existence of man and other animals. Each hour represents 100 million years; each minute represents about 1½ million years.

But this perspective of man's temporal place in the universe suggests other considerations. It gives a pointer to the future of mankind upon the earth. Prof. Julian Huxley in his address to the Zoology Section of the British Association at Blackpool (1936) and many others have speculated upon the near view of man's future. To some it has seemed likely that future progress will be along the lines of individual development, that brains and mind will become more perfect in their working until man is master of all nature. Others look to a future in which not the individual as a unit, but society as an integration of individuals will become more closely knit and more perfect in its functioning.

Still others see in the modern developments and threats of warfare a warning finger of the doom of civilization. I would remind these doubters that evolution as we know it is built upon destruction; that the development of the whole animal kingdom rests upon destruction of green plants, which biologically are formed of the same stuff as we are, and that within the animal kingdom the flesh eaters have risen upon the bodies of their fellow creatures. The drama of wars among mankind seizes the imagination, and history books bias the mind by emphasizing wars and ignoring the quiet but effective work of millions of unknown citizens through the ages. But in our perspective of hundreds of millions of years these are the merest incidents, and war or no war, the quiet progress of evolution flows through life carrying the world of living things steadily but unobtrusively from one step to a higher.

In his short past man has been moving toward a higher intellectual, spiritual, and moral standard, and the biological view would be that in the immediate future (geologically speaking) that movement will continue and that for human beings this future lies in the development and perfection of social life and in the spreading of the social idea to include peoples and nations as well as individuals, with all the correlated advances that these imply.

That is the short view of man's future, but what of the long view of mankind upon the earth? I notice that Sir James Jeans contemplates (1929, p. 338), at any rate fancifully, the existence and progress of humanity until the shadow of the extinction of life upon the earth falls upon the world many millions of years hence. Does our vista of life support such a view?

We must admit that any view of science about the future of humanity can be only a short-range forecast; of the long-range forecast it can say nothing. The reason is that science knows only the past and the present, so that it can read into the future only the glorification or degradation of what has already been expressed in mankind, let us say better brains, better social organization, less self-seeking. Yet the unfathomable characteristic of life is that it is always throwing up something new; evolution proceeds not only by permutations and combinations of the old, but by the emergence of new lines of development. The physicist can foretell with accuracy the movements of the planets, the return of eclipses and comets, but who knowing only fishes could have foretold the amphibia which arose from them, or knowing only the reptiles could have foretold their descendants the birds and the mammals? When we leave details, in the world of living things we can be wise only after the event, we cannot be wise before the event. Therefore the long future of evolution upon the earth is unknowable, so far as science is concerned.

Nevertheless, bearing that warning in mind, we may gain some hint from our perspective of life upon the earth.

We look upon man, and rightly so, as the crowning glory of evolution: stage by stage, we say, the evolution of the past has led up to him; we can imagine nothing higher, evolution appears to have reached its goal.

But step back some 180 million years in our time scale to the Triassic period when the great dinosaurs dominated the earth and nothing higher than reptiles had been evolved. To themselves and to the creatures which shared the world with them, they must have seemed (if they had any self-consciousness), and indeed they were, the crowning glory of creation; stage by stage the evolution of the past had led up to them; nothing higher could be imagined, evolution appeared to have reached its goal. And that could be said by their contemporaries of the highest creatures at every stage in the course of 1,200 million years of evolution, just as it is said of man today. A hundred million years have rolled past since the time of the dinosaurs and they and all their immediate kin have disappeared forever, and new and unforseen trends of life have blossomed, as they have done over and over again, and have carried the story of evolution on to the present, when man is the dominant and highest.

Looking back over that 1,200-million-year vista of the steady climb of life upon the path of evolution, it seems presumptuous for us to suppose that man, the latest newcomer, is the last word or the final crowning glory amongst many, and that with his coming the great steps in evolution have come to an end. Looking forward to the future of life upon the earth, it seems even more presumptuous for us to suppose that for the next 1,000 million years life, so surprisingly inventive in the past, should be tied for all time to come to trifling changes like increase of brain power or better social organization for mankind.

The truth is that we, bound by the past, can imagine nothing more, but if the long vista of evolution is any clue to the future, we cannot regard mankind, the crowning glory of the present, to be more than a stage in life's progress and a milestone upon the path of evolution toward a greater future. To think otherwise is to imagine that with the coming of man, so insignificant in time, the advance and inventiveness of evolution, steadily carried on through an unimaginable vista of years in which no trace of slackening can be perceived, has all but come to an end.

It may seem to you that our perspectives have carried us far afield into a future so remote that it is scarcely worthy of consideration. My excuse must be that we are so accustomed to think of man as the sole significant inhabitant of the world that it is worth while now

and again to look upon him in his biological setting as but one, and yet so far the greatest, of the manifestations of life upon the earth.

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ANIMAL BEHAVIOR

By Ernest P. Walker[1]
Assistant Director, United States National Zoological Park

[With 18 plates]

INTRODUCTION

The everyday life of an animal is a struggle to avoid enemies, to obtain food and shelter, and to reproduce. A single incident of carelessness or ineptitude may result fatally. Hence, in a long process of evolution, every surviving animal species has developed pronounced traits, characters, or reactions adapted to help the creature meet the daily conditions of its life.

The problems of life for all wild animals fall into a few general categories not greatly different from those that confront us. In self-preservation all but a few of the most powerful creatures must be prepared to avoid other animals by fleeing or by concealment, or to fight them off or deter them in some manner. All must be proficient in obtaining food; and, since the food supply of many kinds is not uniform throughout the year such creatures must either (1) store up their winter's supply, (2) go where a sufficient supply of food is obtainable, or (3) make use of the provisions with which nature may have equipped them for storing up reserve energy or for hibernating. Those that live in damp regions ordinarily have no difficulty in obtaining sufficient water whenever they need it. Others must be able to endure long periods without an opportunity to drink. To the great majority of animals a home of some sort is essential. For homes they either use natural shelters or construct or excavate shelters to their liking. All animals have their social problems—whether to live amicably together in communities or to live singly. Some have developed cooperation to a high degree and many recognize the property and territorial rights of others. Voice and communication among animals are much more generally prevalent than is ordinarily supposed. The means by which animals get about are varied in adaptation to the lives that different creatures lead. The

[1] The writer wishes to express his gratitude to Messrs. Gerrit S. Miller, Jr., and Vernon Bailey for advice and suggestions during the preparation of this paper.

care of the young under a wide variety of conditions is of paramount importance in the survival of every species.

The diverse conditions under which the numerous species of animals live have resulted in wide variation in the activities of animal home life. Cleanliness and care of the body covering is probably of as great importance to animals as it is to mankind; for animals do not have doctors and prepared medicines to use in treating their skin should it reach an unhealthful condition, and they cannot go to a nearby store for new clothes if they neglect their one suit. Memory is probably as necessary to animals as it is to us; for, like us, animals must profit by their past experiences, must remember where they have left food stored or hidden, and in other ways must foster their welfare by remembering the things that are of importance to them. Although animals do not generally use tools, certain kinds do so to some extent; and the use of carefully selected materials by animals is rather common. To carry out their varied activities without tools, animals have developed great skill in the use of their hands, feet, tails, and teeth, parts that in many species have been highly modified as specialized tools for special purposes. Efficiency in the daily activities of animals is just as important as it is to us. The inefficient may readily be eliminated in the keen competition of nature, leaving only the efficient to survive. Play and exercise are regularly indulged in by a great number of animals. In short then, we can see in the lives of animals many activities that closely parallel our own.

Few people stop to consider why an animal reacts in a certain way to a given alarm or stimulus. Consideration of such reactions is a fascinating and instructive study. It frequently reveals facts that we can put to good use in our own lives.

The activities of any species of animal would supply the material for an extensive study. Therefore, in this article the most that I can do is to point out a few facts regarding a number of animals. The facts that I shall bring forward are by no means lone instances of interesting behavior. Indeed, an observer with a sympathetic viewpoint will find that almost every action of an animal is interesting because of its definite relationship to the creature's mode of life. If a particular kind of behavior appears to be without reason, it should suggest to the careful student that he does not know enough about the animal to comprehend the significance of the action.

Most animals operate under rather definite time schedules, having fairly definite times for sleeping, waking, and feeding, each species following its own schedule. The clocklike regularity of certain individuals in adhering to the schedule is surprising. The carnivores are

probably the least regular. I have observed that each of my pet pocket mice (*Perognathus*), kangaroo rats (*Dipodomys*), and grasshopper mice (*Onychomys*) had its own very definite time to wake up and to go to bed. One little pocket mouse would come out of his nest about 4 o'clock in the afternoon during the winter. With the approach of spring and the lengthening of the days he did not get up quite so early; and during the longest days of summer he did not appear until about 7 o'clock. Another individual of the same species, "Bitty," regularly stayed in bed until about an hour or an hour and a half later in the evening. In the morning I found that both were almost invariably in bed by daylight.

SELF-PRESERVATION

"He who fights and runs away, may live to fight another day" generally holds true throughout the animal kingdom, for animals do not ordinarily seek encounters with others unless it be to obtain food, shelter, or mates. Combats to the death are rare. By the elimination process that nature has followed so successfully, the individuals that are strong and vigorous in searching for food, in capturing their prey, in fighting for their homes or in gaining mates are enabled to perpetuate their characteristics, while those that are weaklings in these contests are not.

The methods of avoiding detection or of being caught in dangerous situations are, like the methods of escaping from enemies, even more numerous than are the species of animals, for each species has many problems of this kind to solve.

Many human beings are definitely opposed to any new proposal, particularly if they do not fully understand it. This is merely a remnant of a trait that is essential to the preservation of an animal species. For animals must be suspicious of anything they do not understand, such as strangers, unaccustomed food, or new surroundings. The stranger animal may be dangerous, the food may be poisonous, or the surroundings may conceal a trap; hence the animals that are not suspicious and do not convince themselves of the safety of a new thing before they try it may be eliminated.

Since self-preservation is the first impulse of the individual and is essential to the perpetuation of every species, all animals must have some means of defense. All too frequently we think of animals in the terms of whether or not they are dangerous or vicious. In general, they are not dangerous except when they find it necessary to put up a show of force to stop aggression. On this subject, it may be said that when animals appear to us to be vicious, savage, or ill-tempered, this is almost invariably their way of warning us to leave them alone, of letting us know that they do not want trouble and that they are cour-

ageous enough to fight in their own defense. Very rarely does a wild animal attack without first-class provocation.

There are many modes of animal defense. One of the most effective and well known is the method used by the skunks (*Mephitis*, *Conepatus*, and *Spilogale*), peaceful animals that desire only to be let alone to lead their own quiet, inoffensive lives. They are too slow to escape by running and are not equipped for a fight; but below and on each side of the base of the tail is situated a gland that secretes a vile-smelling liquid. This material can be sprayed in two fine jets to a distance of several feet to the rear of the animal. Therefore, when danger threatens the little fellow heads away from the enemy, raises his tail and stands in defensive attitude. If the enemy has not had previous experience it may be so incautious as to approach and attack. In such event, it is almost certain to have regrets, for the spray of a skunk is intensely irritating if it gets in the eye, is nauseating to most animals, and is remarkably persistant in its duration.[2]

The term "playing 'possum" is well known in the range of the North American opossum (*Didelphis*) as a synonym for feigning death. In general, when an opossum is disturbed, it will become limp and allow itself to be handled in almost any manner without making an effort to fight or to run away. This undoubtedly is a very effective means of avoiding molestation by animals that are not particularly interested in eating an opossum but would worry or attack it should it move or try to escape. The opossum has a peculiar odor and is probably not relished by many animals for food. Most dogs soon lose interest in an opossum because it offers no resistance to them. This feigning of death is thought by some zoologists to be a paralysis induced by fear.

Just how effective a means of defense spitting in the face of an enemy may be is not known to me, but the South American representatives of the camel family (llamas, alpacas, guanacos, and vicuñas) habitually resort to it. When irritated the llamas and their relatives spit toward an enemy. Perhaps this is effective for the protection of the animal under some circumstances, but I do not know what dangerous natural enemy it may deter.

In Alaska I once had occasion to investigate charges of unprovoked attacks by the big brown bears (*Ursus*), the largest of all carnivorous mammals. In practically every case I found that the attack was not wanton or unprovoked. Sometimes a man would be

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[2] There is a common belief that clothing that has been scented by the skunk's fluid must be buried in the ground for a long period. Numerous other treatments have been proposed. Within about 15 minutes strong, fresh skunk scent can be reduced until it is not seriously offensive by exposing it to ozone which is now readily available from small electric ozone-producing units used for purifying air and dispelling odors.

walking along a trail and a bear would be going in the opposite direction. They would meet face to face and the bear would try to get away in the direction it was headed. In doing so, it would frequently knock over the man, sometimes mauling him a little; but the bear would always run away if it had a chance. On other occasions the man had shot the bear but had not killed it, and the bear was merely fighting an enemy to save its own life. In at least one instance a man had clambered over a log in a dense forest and had jumped down on a sleeping bear. Naturally, the bear woke up fighting, as from its viewpoint it had been attacked. The most frequent occasions of so-called attacks were when men had tried to capture bear cubs or had in some way frightened the little fellows, who set up a cry for mother. As mother is a courageous creature, she rushes to the rescue, frequently with disastrous results to the man. In none of these cases could I feel that the bear was to blame, for viewing each situation from an entirely disinterested angle, it was obvious that the bear was in the right.

Most carnivores who engage in combat must protect their ears and eyes. Good examples of animals that get their ears out of the way in attacks are the cat and dog, both of which lay their ears back when danger threatens. This action is not merely intended to produce a more ferocious expression. Its chief purpose is to get the ears down as close to the head as possible where they will be least in danger of being bitten or scratched. The eyelids are partially closed and the eyebrows are drawn down to protect the eyes.

Most of the common rabbits (*Sylvilagus*) and hares (*Lepus*) in the United States live mainly above ground and are exceedingly swift-footed and alert to avoid the host of enemies that prey on them. If they were not alert they would not survive in the exposed locations where they regularly live.

In marked contrast to the behavior of the rabbits is that of a host of the small mammals that have their dens, nests, or burrows in the ground or among rocks where but few enemies can reach them or where enemies can reach them only after considerable digging. These little creatures instead of taking immediate alarm and fleeing at the first disturbance remain perfectly quiet in their dens, where the enemy, unless able to detect them by scent, has no means of knowing they are at home. Notable among these little creatures are the pocket mice (*Perognathus*) and kangaroo rats (*Dipodomys*), charming, dainty little creatures that bear only a superficial resemblance to mice or rats. They are highly specialized rodents that live in the western United States and in Mexico. Some of them occupy the areas of wind-blown sand or sections where the vegetation is exceedingly sparse and where protective cover is very sparse

or entirely lacking. The tiniest of these rodents are the silky pocket mice which weigh only from 7 to 10 grams and have fur so fine and silky that it can scarcely be felt with human fingers. They dig burrows about three-quarters of an inch in diameter into the soft sand, preferably selecting a location near a sagebrush or greasewood or some other kind of desert plant. They close the entrance to the burrows when they go out and when they come in so that enemies may have more difficulty in finding the entrance. It must also be remembered that on warm dry sands, scent does not remain long. Therefore, the enemies that would hunt them by scent have no trail to follow a short time after pocket mice have passed by.

The little hedgehogs (*Erinaceus* and related genera) that feed mainly on insects and small snakes are also believers in passive resistance. Their bodies are clothed with a dense coat of short, fairly sharp spines that are more securely attached to the skin than are the spines of the American porcupines (*Erethizon* and *Coendou*). Around the lower edge of the body there is a circular muscle that acts as a draw string. When danger threatens, the little fellow tucks his head beneath himself, pulls in his legs and very short tail, then tightens the draw string. This very effectively pulls him into a ball about the size of a grape fruit, with his head, feet, legs, and tail well enclosed near the center. At the same time the spines are erected so that the animal appears as a spiny ball. In this form he is quite inaccessible to almost any enemy.

The tactics of porcupines in both the Old World and America are alike. When danger threatens, they merely turn their backs to the intruder and let him hurt himself on their spines. However, the North American porcupine (*Erethizon*) adds a bit to this trick by giving a quick sidewise switch of his tail when the enemy is near. This often drives the barbed quills into the flesh of the enemy, making painful wounds; and the movement is so quick that many people believe that the porcupine throws its quills. Such however, is not the case. The large African porcupine (*Hystrix*) will charge backward when an enemy is close. The spines of porcupines are very lightly attached to the skin. Usually they stick into and stay with the victim. The quills of the American porcupines are barbed at the tips and so penetrate deeply into the enemy's flesh. The quills of Old World porcupines are not barbed. Some are merely flattened bristles often deeply grooved longitudinally.

Many small rodents have remarkable abilities of leaping over distances equal to many times the animals' own length. Some kinds can leap backward or sidewise as well as forward in an incredibly short time from the actual alarm—in fact, so quickly that the human senses do not detect the lapse of time from the alarm until the animal

is at a new point of rest. This is a valuable accomplishment to many little creatures whose chief danger usually lies in attacks from predators such as snakes, cats, weasels, owls, hawks, or other creatures that strike or grab with lightninglike rapidity. Therefore, if at the first instant of alarm the intended victim changes his first location to some other he will probably be safer than before; and if he follows this up with further prompt get-aways, he will frequently avoid capture.

I have observed that small mammals are much disturbed by the rattling or crumpling of paper or cellophane. If this sound is continued they soon become nervous and seek shelter. I have no proof as to why they react in this manner, but I feel certain that it is because the rattling and crackling of paper reminds them of the sound of enemy footfalls on dry leaves.

Gibbons (*Hylobates* and *Symphalangus*) are the most agile acrobats among the primates. They literally fly through the trees in great swings with their long arms, and they are so thoroughly at home in the treetops that they have little to fear from enemies. But they are not so free from danger when they are on the ground, which consequently they are loath even to touch. When they drink from the pools or streams, they prefer to hang by an arm and a leg from a branch or vine, merely dipping the somewhat folded hand into the water and raising it to the upturned mouth. This method of drinking can be frequently observed in a zoo. Gibbons are also adept in eating oranges. Instead of making a messy job of it as many animals do, they will, if given sections of an orange carry them to their mouths in their hands and direct their mouth upward so that scarcely a drop of the juice is lost. In their native haunts they are accustomed to eating many kinds of juicy fruits.

The gerenuk (*Litocranius*) is an African antelope of extremely tall and slender build much like the giraffe in form but standing only about 3 feet high at the shoulders and perhaps 5 feet high to the top of the head. This little creature inhabits a region of very sparse vegetation where concealment would ordinarily be difficult. It has apparently learned that it can best escape from its enemies by lying down flat on the ground. A young one that was perhaps one-third grown when it was first placed in its cage amid strange surroundings in the National Zoological Park at once took this position.

The giant eland (*Taurotragus*) which is almost as large as a horse and inhabits the barren plains of Central and South Africa has a similar habit of lying flat on the bare ground.

Innumerable other instances might be mentioned of the methods used by animals in looking out for their own welfare. There might be cited and discussed at length the manner in which animals remain motionless and by their color pattern blend with their sur-

roundings so well that their coloration is their chief protection. Extreme alertness and the ability to slip away quietly and unobtrusively at the first sign of danger are common and effective safety devices.

OBTAINING FOOD

Since all individuals of all kinds of animals must obtain their food under the conditions peculiar to their respective ranges, there is an almost infinite variety in the methods of animal food-getting. Each of these methods, of course, is well adapted to the physique and mentality of the animal and to the conditions under which the food must be obtained. Some animals live only from meal to meal, others hoard food for periods of scarcity, and still others arrange to avoid eating during periods when food will not be available. Some animals must make radical seasonal changes in their diets to be able to survive.

Animals that live in the midst of a food supply that is generally plentiful, as for example horses (*Equus*), cattle (*Bos*), sheep (*Ovis*), rabbits, and many others, merely have to look about them and select the kind of food they prefer. Sloths (*Bradypus* and *Choloepus*) feed almost entirely on leaves, and, since these mammals live only in the Tropics where the trees are green throughout the year, their problem of obtaining food is very simple. They merely climb a tree that produces the kind of leaves they like and remain there indefinitely. In some cases at least, sloths appear to live practically their entire lives in a single tree.

Porcupines, in the northern portion of North America, have almost as simple a food problem as the tropical sloths. Although, unlike a sloth, a porcupine is quite capable of traveling on the ground, one of these prickly rodents may take up its abode in an evergreen tree that has bark to its liking and remain there during an entire winter, or at least until it has eaten practically all the bark from the small twigs and branches.

Other creatures must hunt for and capture their prey or must search industriously for tiny particles of an inadequate food supply. A good example of the latter problem is the struggle for existence by the tiny pocket mice. The homes of these small rodents are simple burrows in the barren sandy or rocky deserts of the southwestern United States. The burrows may be from a few inches to 2 or 3 feet in length with from one to three chambers at the end. One of these chambers is the storehouse. The animals usually go out early in the evening and industriously search for every seed they can find. These they put into their fur-lined cheek pouches. When they have obtained a load of seeds they return to the burrow and deposit their valuables in the storehouse. Thus they make trip

after trip over as wide a radius as they can safely traverse or until they encounter the opposition of the occupant of another range. If the seed crop is good they may thus accumulate a supply of seeds sufficient to last them for several years. In this respect nature has taught them well; for there are times when the seed crop is a total failure during periods of a year or more, and, in a dry region where the food supply is scant, the little creatures would starve to death if they did not have adequate supplies laid up.

Pocket mice are very frugal. Apparently they never overeat. If they did eat excessively they would unduly deplete their food supply so that when a food shortage arrived they would have nothing to tide them over it. Competition for food in the region inhabited by them is so keen that the smallest kinds apparently have to start out first in the evening to get their share. They generally lead solitary lives. If two meet they almost invariably fight, until one is killed or driven off. Evidently they have found through the ages that a given area will produce only enough seeds to support a limited population. Therefore, in order that the population may be evenly distributed, they live alone, each within his own territory in which he must maintain himself. If they adopted a colonial habit it would be necessary for the individuals to range much farther from their homes to obtain food supplies, thus greatly increasing the hazards from enemies. If the burrows of pocket mice are disturbed, the animals feel that their stores are threatened. Therefore, as soon as it is dark and the disturbance has subsided, they begin industriously to move their seed supply to another place that they consider safer.

The kangaroo rats, larger cousins of the pocket mice, lead similar lives but dig larger burrows. Some of them make large mounds of earth and elaborate storerooms. They range somewhat more widely than their smaller relatives. They likewise store up seeds that they carry in their furlined cheek pouches to their treasure rooms. However, there appears to be one exception to this rule. One of the smallest species of kangaroo rat (*Dipodomys merriami*) is frequently found entering the burrows of the larger kinds and is not known to store up food supplies of its own. It is suspected of having adopted more or less parasitic habits and of living chiefly on the stores hoarded by its larger relatives. The pets of this species that I have had have shown no disposition to store food.

The grasshopper mouse (*Onychomys*) of the southwestern United States is largely a carnivorous rodent, for, in addition to seeds, fruit, and plant tissues, it eats insects (particularly grasshoppers), crickets, beetles, scorpions, lizards, and mice. Its technique in obtaining prey is singularly effective and well adapted to its type of life. It follows

a fresh track like a hound, makes a slow and very careful approach, and, when within reach, grabs its prey, usually with its teeth but sometimes with its hands. This action is so quick that the human eye can scarcely follow it. At the same time the eyelids close almost completely over the rather prominent eyes, thus protecting them from injury by the sharp claws of insects or other weapons of the prey. If the victim is a mouse or other creature nearly that size, the attack is particularly savage, much like that of a little bulldog, although the grip is not quite so tenacious, the hold being occasionally changed to obtain a more effective killing grip. The quick, firm grasp is necessary to prevent the prey from escaping; if not firmly held a grasshopper or cricket might leap or a butterfly or moth might fly or a worm might retreat into its burrow. The grasshopper mice contrast sharply in form with the slender, delicate, graceful build of most of the small rodents. Leading predatory lives they are built like little prize fighters. Both fore and hind legs are short; likewise, the tail. The body is short and powerful. While the teeth are essentially like those of a deer mouse, they are so modified as to be effective for grabbing, holding, killing, and chewing insects or warm-blooded prey. A grasshopper mouse has need for his large ears to help him detect the faint sounds made by insects or other prey. He also needs good eyesight; and he apparently is able to detect moving objects at a much greater distance than is possible for a pocket mouse or a kangaroo rat.

The raccoon or coon (*Procyon*) obtains much of its food along the margins of streams, lakes, and coasts, where frogs, mussels, crayfish, crabs, fish, and other edible creatures are readily obtainable. These are, of course, frequently caught in shallow, dirty water or on the mud and consequently are likely to be dirty or covered with sand. The raccoon has, therefore, formed the habit of systematically washing all its food before eating. It is entertaining to watch captive raccoons take their perfectly clean food to their dish of water and solemnly give it a thorough washing before they eat it.

Bats (order *Chiroptera*) have developed remarkable techniques in meeting the problems of survival in a largely aerial habitat. Some bats that live mainly on fruit have adopted a nomadic type of life in order that they may shift from one locality to another to be where fruit is ripening or to obtain the flowers on which some of them feed. Naturally the bats depending mainly on fruit and flowers must limit their range to the Tropics, for unless they were to hibernate they could not survive the long periods in the temperate zones when fruit and flowers would not be available.

The greater number of the smaller bats feed on insects that they capture on the wing. To be able to do this they have developed

remarkable ability to turn and twist and dodge about in the air. Apparently their hearing and touch—and perhaps some other sense unknown to us—are remarkably developed to aid them in locating their prey. It is obvious that the expression "blind as a bat" is utterly without foundation, for the most casual observation of bats shows plainly that these animals can see keenly for considerable distances and that they are exceedingly watchful.[3] No doubt their eyesight is highly specialized in order that they may, while on the wing, detect minute insects and successfully capture them. Since insect food, when it is available at all, is generally very plentiful, most bats need not lead solitary lives as do many of the animals that live under conditions in which food is generally at a premium. They, therefore, frequently congregate in great numbers in caves, houses, hollow trees, or other convenient roosting places. Since their fingers serve only to support the wing membranes bats would appear to be handicapped in capturing and holding insects. However, they have very successfully overcome this difficulty by developing a remarkable flexibility of the neck, and an extreme dexterity of the wing. Turning and twisting in the air a bat successfully follows erratic insects.

The blood-drinking bats (*Desmodus* and related genera), commonly known as vampires, are small animals about the size of our common brown bat (*Eptesicus fuscus*) that have developed a wonderful technique in obtaining their food. When they find a warm-blooded victim—horse, cow, sleeping bird, or person, as the case may be—they settle on to it so gently that the victim is usually not aware of their presence. With their peculiarly enlarged razor-edged incisor teeth, they then cut off a very small thin layer of the skin, going just deep enough to cause the blood to flow. This is so neatly done that the victim is usually unaware of the presence of the bat as it quietly laps up the blood that oozes from the wound. Ordinarily the amount of blood lost by the animal is not excessive. The principal danger from the attacks by vampires lies in the possibility of infection of the small wounds.

On the southeastern Alaskan coast I have often observed the little Northwest fish crows picking up clams or mussels on the beach at low tide and flying directly upward, 20 to 40 feet, then dropping the shellfish on the rocks below. The birds then fly down and examine the morsel. If the shell is sufficiently shattered they proceed to eat the meat. If it is not broken they pick it up and drop it from a greater height.

[3] Experiments with bats that had been blinded disclosed that they could avoid threads while flitting about in a dark room. This suggests the existence of some other sense, perhaps unknown to man, that aids them in the dark.

Snakes, without hands or feet to assist them in capturing and holding their prey, would seem to be at a considerable disadvantage. However, they have evolved very effective methods. The quick seizure of a victim with the mouth and the throwing of the coils about it by some snakes is generally well known. However, many snakes do not use this method of capturing their prey. The poisonous snakes merely strike their victim and bide their time, making no effort to seize it until it has died from the poison they injected with their hypodermic-needlelike teeth. When the victim is dead, the snake, beginning at the head, gradually engulfs its prey by working the upper jaw and lower jaw alternately forward over the victim. Those nonpoisonous snakes that do not kill their prey by constriction slowly swallow it alive.

The archer fish (*Toxotes*) regularly obtains its food, consisting chiefly of insects and spiders that are resting on overhanging vegetation, by expelling a drop of water from the mouth which goes with force and accuracy and knocks the victim down to the surface where the fish can catch it.

Most animals, like many people, are rather slow to eat freely of foods with which they are unfamiliar. It is interesting to watch them become acquainted with new foods. They usually approach very cautiously as though confronted with a dangerous object, "sniffing" it carefully. Their "sniffing" frequently satisfies them in one way or another. Either they do not touch the inspected object at all or they proceed to eat it freely. Occasionally the taste of the food does not appear to have agreed with the judgment of it based on scent, and they quickly lose interest after taking a taste of it. An animal's technique of eating a new food is sometimes amusing. On one occasion I saw a kaibab squirrel (*Sciurus kaibabensis*) given a section of an orange with the peeling left on it. He picked it up and started to eat from the peeling side, but quickly realizing that that was not the proper way to eat this new kind of fruit, he turned it over and worked from the meat side. Thus he made a thoroughly clean job of eating out the good portion of the orange.

Fortunately, animal life is not as a rule destructive of its food supply. It is true that a few animals, such as weasels and their relatives, will kill as long as victims are available, but, in general, most creatures kill or harvest only what they actually need for their own immediate food, or for a future food supply. However, such habits of storing food are generally not harmful to the plants on which the animals are dependent for a living. For example, the seeds stored by the little desert rodents will, if not consumed, sprout and produce a new crop when weather conditions become favorable. Likewise the nuts harvested and buried by squirrels often develop into nut-bearing trees.

DRINKING

We usually think of water as being fully as important as food to living creatures. Such, however, is not true in many instances. Animals that live in desert regions have, through long periods of evolution, developed ways of surviving with a minimum of moisture obtained from their food. The most specialized of these are some of the rodents such as the pocket mice and kangaroo rats of the southwestern United States, the jerboas (*Jaculus*) of Asia and northern Africa, and many others. These mammals live in regions where the rainfall is very scant over much of their range and where water is practically unobtainable. They have, theretofore, become adapted to living with almost no water to drink. During the very short time when there may be green vegetation they may eat some of it. At other times they obtain no moisture except perhaps an occasional drop of dew; but their needs are adequately supplied by chemical processes that take place within their own bodies, where the constituents of dry seeds and other vegetable food are converted into moisture by oxidation.

Vernon Bailey, for many years Chief Field Naturalist of the United States Biological Survey, has taken unusual interest in the desert animals and has discussed in an admirable manner their problem of obtaining moisture.[4] He has found that many animals of arid regions eat roots, tubers, and fleshy stems of plants such as cacti and others that contain a high proportion of moisture even during periods of drought, in this way probably obtaining all the water they need without having to manufacture it by oxidation.

I have often offered water to pocket mice, kangaroo rats, grasshopper mice, and other desert animals to make certain that they did not suffer from lack of moisture. Almost invariably they refuse it, though occasionally they may sip a little and then not touch water again for months.

One pocket mouse, however, a very old male, took to using water rather regularly. He lived in captivity 8 years and was apparently adult when captured. It may be that as he became older his normal ability of converting dry food into moisture became impaired so that he required moisture in order to survive. It is possible that the unusual care that I gave him enabled him to live to a greater age than he could have reached in a wild state. Another animal of the same kind seemed greatly offended when I offered her water. On a few occasions I dropped a single small drop of water on her and was much amused by her violent antics of rolling in the sand to remove the offending substance from her coat. I am convinced

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[4] Bailey, Vernon, Sources of water supply for desert animals. Sci. Monthly, vol. 17, No. 1, pp. 16–86, 1923.

that she never took water during $2\frac{1}{2}$ years. Very rarely did she show the slightest interest in eating any moist vegetation. She subsisted almost entirely on dry seeds. The one now living on my desk likewise abstains from water and eats very little green food. My grasshopper mouse, "Ony," will take water occasionally but will frequently go for intervals of a month or more without drinking. It is likely that in the wild state the blood or body fluids of its victims would supply one of these animals with most of its required moisture. To make certain that my pets never suffer for moisture I regularly make lettuce or other green material available to them.

Camels take considerable water when they have the opportunity. Instead of being stored in large cavities as some of the early zoologists led us to believe, this water is really kept in small cells in a semiporous lining of the stomach. The absence of sweat glands in the skin of the camel reduces greatly the loss of water from evaporation. The camels' nostrils are slits that can be closed. They lead into a groove in the upper lip that enters the mouth, this arrangement making it possible for drainage from the nostrils to be returned to the body.

Antelopes, deer, bighorn sheep, and other desert animals not only survive but thrive for considerable periods without drinking. However, they usually find some vegetation that contains moisture in small quantities. Many desert creatures do not know how to drink in the ordinary manner. Frequently they stick their noses into the water and strangle, without getting their mouths into it. More often they dip their hands in the water and lick their fingers.

On one occasion I observed a thirsty prairie dog (*Cynomys*) put his nose into a pan of water. He held his head down at such an angle that his nose went into the water but his mouth did not. He sat up wiped his wet nose with his hand, sneezed, then dropped down on all four feet and put his head at a flatter angle so that he was able to drink. This is quite a common mistake made by the little animals that are not accustomed to drinking or that drink at only very rare intervals. They probably sip or lap up drops of dew on the rare occasions when dew occurs in their region. In captivity the little fellows can be given water on a bit of lettuce leaf or a saturated wisp of absorbent cotton.

Amphibians and certain lizards do not drink. They obtain water by absorbing it through the skin. I have placed an emaciated lizard of this kind in a pan of shallow water and watched its skin take up the moisture like a blotter.

MAKING HOMES OR USING SHELTERS

Just as every animal has a fairly definite territory within which it lives, so also it usually has a house or shelter of some sort. Some

animals merely utilize whatever natural shelter is available. Others exercise considerable ingenuity to construct a fairly definite type of home.

Prairie dogs build a very definite type of home. It consists of a burrow that may go 15 feet or more almost straight down into the ground with 2 or 3 small chambers at the end. One of these chambers is the real nest; another is a little toilet room; sometimes there is a spare room; and 2 or 3 feet below the entrance of the burrow is a little shelf which is used as a sentry station.

The plains prairie dog usually heaps up a volcano-shaped cone at the entrance of the burrow. The entrance is at the top of the cone. This arrangement prevents water from getting into the burrow should the land be flooded by heavy rain. The little fellows can sit on the crater's rim or inner slope. If alarmed they merely tumble into the burrow, disappearing in an incredibly short time. The manner in which they maintain this crater is particularly interesting. Earth is pushed and kicked out of the burrow and is gradually built up around the entrance. If it is necessary to build the crater rim higher and soil is not being brought up out of the burrow, they go to the outer base of the cone, dig earth loose with their forefeet and teeth, kick it backward with their hind feet up toward the center of the cone and then turn around and push the loose soil with their hands and chests. When the loose soil is finally in place, they pat it with their forefeet and tamp it very firmly with their noses. The nose marks can regularly be seen in fresh, well-kept prairie-dog burrows.

It is particularly amusing to see prairie dogs working the first thing in the morning after a heavy rain. Almost every individual of the colony is industriously cleaning out its burrow or repairing its cone, pushing the soil into place and tamping it with its nose. In captivity they are fascinating to watch for they are active by day, and if they have not been persecuted they soon become friendly and go about their everyday lives as though they had no spectators.

Moles (*Scalopus*, *Talpa*, and other genera) are related to the shrews (*Sorex* and related genera) and inhabit North America, Europe, Africa, and Asia. Most people who live in their range know these animals by their work; but very few persons have actually seen them at work. This is because moles spend almost their entire lives a few inches under the surface of the ground burrowing in search of insects. Their burrows appear generally at the surface of the ground as raised ridges of earth, which may be annoyingly conspicuous when they cross well-kept lawns. This burrowing is really a process of forcing upward and to the sides the earth loosened by the animal as it forces itself ahead, digging to the right and left with its broad spadelike front feet armed with long, sharp, straight claws and lifting the forepart of its body when it wedges itself into

the hole it is making. It is surprising how rapidly a mole can progress by this method. After the runway is completed, the animal traverses it without further digging other than enough to keep it open.

Gorillas (*Gorilla*) live a seminomadic life. They remain in a given vicinity only a few days and then move on to another where the food supply or other conditions may be better. In order that they may add to their comfort they bend the limbs of trees and shrubs so as to make crude platforms that are utilized by the females and young as beds or hammocks. Generally an old male does not use a platform; perhaps because he is too heavy for that type of construction. Orangutans (*Simia*) make similar platforms in the trees.

The work of the beaver (*Castor*) is too well known to require discussion other than to point out that these animals make two types of houses, one a mound out of the center of which they hollow a living chamber, the other a living chamber excavated in a stream bank. Both have tunnels that lead into water that is ordinarily so deep that it does not freeze to the bottom, so permitting the beaver to go out of his house and return regardless of the weather. In order that beavers may have uniform water levels adjacent to their houses, they build dams of sticks, stones, and earth. Such dams are sometimes as much as 12 feet high, and some have been found that, although not so high, were as much as 550 feet in length. The average dam is perhaps 75 feet long and 3 feet high.

The tropical American fruit bats (*Artibeus* and *Uroderma*) have adopted the practice of making shelters by biting the fronds of certain kinds of palm in such a manner that the edges of the fronds bend downward so as to form roofs beneath which small groups of the animals can find shelter from daylight and from rain. Visitors to the Panama Canal Zone can easily inspect some of these remarkable shelters in the Botanical Garden at Summit.

Birds' nests are the best known of animal homes. They are conspicuous and have been known by mankind since primitive man first sought them for the eggs and the young he might obtain. The casual observer may think that a bird's nest is merely a collection of sticks and twigs in a tree but in reality each kind of bird builds a nest of a type peculiarly its own. For example, the Baltimore oriole (*Icterus galbula*) builds a deep sack-shaped nest pendent from the tips of the limbs. It is really a woven fabric bag. The vireos (*Vireo*) on the other hand, weave cup-shaped nests usually set in a horizontal fork so that the nest is slightly pendent, though it is no deeper than wide. In Africa the social weaver birds (*Philetaerus socius*) live together

in colonies, each pair building its own nest. But the nests are constructed close together and are so interwoven that they form a single mass sometimes as much as 8 or 10 feet in diameter to which each pair of birds has its own separate entrance.

The tailor birds (*Sutoria* and *Orthotomus*) sew up the leaves of trees to make cone-shaped enclosures in which to build their nests.

Variations in the structure of birds' nests could be discussed in far greater detail than is here possible. Every species has its special type of architecture. And then within each species there are individual peculiarities of construction, for individual birds have their own traits and preferences in nest building.

Horned lizards (*Phrynosoma*), frequently though misleadingly called horned "toads," inhabit the western United States and range southward into Mexico and Central America. They live on the hot sands and are very sensitive to any drop in temperature. As soon as the sun goes down they usually burrow into the sand in order to enjoy its warmth through the night. Captive horned lizards follow this same habit in the zoo. The cage may show considerable activity during the bright hours of daylight; but with the approach of heavy shadows each animal burrows into the sand, sometimes leaving the head in sight, sometimes only the tips of the horns. Sometimes they bury themselves completely, leaving no evidence of their presence but a little ridge or disturbed spot in the sand.

The houses of insects are noteworthy and of great variety. Most people are more or less familiar with the fact that ants live in colonies and have elaborate colonial homes. Wasps and bees are also well known for their homes. The masses of webs that are frequently found in trees are usually the homes of caterpillars. The subterranean burrow made by the digger wasp (*Sphecius*) in which the female lays her eggs and places cicadas that she has stung into a comatose state, may well be called a home for the young wasps that will hatch from the eggs and will feed on the comatose cicadas.

Trapdoor spiders and other spiders generally have elaborate and very effective homes.

Even some fish have homes, for many parent fish construct definite nests in which they deposit their eggs. Conspicuous among these nests are the beautiful little bubble nests made by the fighting fish or bettas (*Betta*) of the Oriental region. The male blows a nest of bubbles, then carefully takes the eggs in his mouth and blows them into the nest where they are constantly tended by him. He constantly restores to the bubble mass any eggs or any young fish that fall out while too small to be ready to go on their own way.

HIBERNATION, ESTIVATION, AND OTHER PROVISIONS AGAINST PERIODS OF FOOD SCARCITY

Hibernation, the winter sleep of some animals, and estivation, the summer sleep of a few others, are remarkable provisions of nature to permit certain creatures to survive periods of cold, heat, or food scarcity, with the minimum of hazard. These two peculiar types of sleep appear to be essentially the same as ordinary sleep so far as physiological phenomena are concerned; every gradation seems to exist between them. But, in hibernation and estivation, breathing is greatly reduced and in some instances of hibernation at least, it may cease for hours at a time. The body temperature of a hibernating animal may drop considerably, sometimes becoming practically the same as the surrounding atmosphere. In other instances, it remains at a fairly constant low level but above that of the surrounding atmosphere. The heart beat is greatly reduced and digestive processes are suspended. Some animals remain in this condition for months at a time. Others for only a day or so at a time. If disturbed while torpid, they generally soon regain activity. Apparently animals must be in at least a fairly good state of flesh before they can enter hibernation. If they were not, they might not have sufficient vitality to survive a long sleep.

Temperature is only one of the factors that determines when animals should go into hibernation or estivation. In fact, although extensive studies have been made of this phenomenon, much yet remains to be learned.

Some animals that live in the rigorous climates of the extreme north do not hibernate, while others do. In the temperate regions many hibernate. Some of these, notably the ground squirrels of the western United States and probably those of Siberia as well, continue their summer sleep into their winter sleep. In the arid portions of both the Tropics and the temperate regions estivation enables the creatures to avoid the intense heat and dryness and in some instances, the food shortages or other adverse conditions such as the drying up of water. Lung fish, northern turtles, and some other animals undergo the same periods of torpor. Practically all reptiles and amphibians in temperate regions hibernate, and some of those in the arid Tropics estivate.

Both hibernation and estivation are practiced by many forms of invertebrate life, chiefly insects, mollusks, and arachnids. No birds are known to hibernate.

The hibernation of bears wherein the animals become exceedingly fat in the fall and select a sheltered den in which to "sleep" throughout the winter is too well known to require comment other than to point out that it is a remarkably good provision of nature to permit

the animals to survive in rigorous climates through periods when food is generally very scarce.

In the northern portion of their range, the prairie dogs (*Cynomys*) make a complete and long hibernation, that is to say, they go to sleep in the fall and do not come out until spring. Farther south they come out during the winter if the weather is unusually mild; and in the southern portion of their range they scarcely hibernate at all. Prairie dogs, it must be remembered, are not dogs at all. They are burrowing squirrels closely related to marmots (*Marmota*).

Woodchucks (*Marmota*) are, of course, noted for their habit of sleeping through the winter. While their movements on February 2 are of absolutely no importance in indicating the kind of weather to be expected during the following 6 weeks, much popular interest is taken in the springtime emergence of these animals.

Skunks in the north remain in their dens all winter and are frequently not to be seen for days or even weeks during the worst winter weather. During these periods they are almost in hibernation. However, a slight moderation of the weather will bring them out; so theirs is only an incomplete hibernation.

Many rodents not only hibernate but go into estivation in midsummer or late in the summer. In many cases it continues into the winter sleep. Notable among these estivating rodents are a number of species of Spermophiles or ground squirrels (*Citellus* and *Spermophilus*) of the western United States that put on fat during the early summer when food is abundant and temperatures are favorable. In the hottest portion of the summer when food in some cases has become scarce they go to sleep in burrows deep enough in the ground so that the temperature does not affect them and they do not have to worry about the drought or the food supply. Some individuals emerge for a short time in the late summer or early fall but many of them continue their summer sleep into that of winter.

The pocket mice and kangeroo rats go into hibernation as soon as the weather is a little chilly in the fall and remain curled up in little furry balls for months at a time. They do not emerge until the weather has become warm. Apparently a temperature of about 50° to 60° will cause some of them to hibernate.

The common chipmunks (*Tamias* and *Eutamias*) that are so conspicuous during the summer do not truly hibernate through most of their range. They merely stay under shelters and in their homes. When the weather is severe or inclement they must feel like many people, sleepy and loath to go out.

In the 1910 edition of the Encyclopedia Britannica it is stated that in some of the northern Provinces of Russia where food is very scarce and the winter climate severe, the people have adopted a mode of

living in winter that is almost hibernation. If we will consider our own feelings on many days when the weather is bad, we will see how easy it might be to go into a partial hibernation even though we lack the specialization that makes it possible for the furry creatures to hibernate so successfully.

Many animals that do not hibernate encounter more or less alternating periods when food is abundant and when it is scarce. Some of these have developed remarkable methods of providing for the lean period. The stump-tailed lizard or shingle-back lizard (*Tiliqua*) of Australia, the Gila monster (*Heloderma suspectum*) of the southwestern United States and its relative, the beaded lizard (*H. horridum*) of Mexico, lay up considerable masses of fat in their tails. These fat masses become large enough to serve as reservoirs of energy during periods when food is scarce. The camel carries his reservoir for energy in his hump. If a camel's hump is erect and plump, it shows that he is in good condition and should be able to stand a period of food shortage without serious injury. If, however, his hump is flabby it shows that he is not prepared to do without food or to go on short rations, although he may be in satisfactory condition so far as day-to-day living is concerned.

The little fat-tailed lemur (*Cheirogaleus*) of Madagascar likewise carries his reservoir of energy food in his tail which he greatly fattens in seasons of plenty and draws upon in periods of scarcity.

Some bats hibernate in caves, buildings, hollow trees, or other locations where they can obtain a fairly uniform temperature of about 46° to 54° F. Great numbers of bats are frequently found in such locations. Other bats migrate like birds, but almost nothing is known about the exact courses and dates of their movements. It can merely be said that they go south to escape the winter and return north in the spring; the details of their flights are yet to be discovered.

Birds meet the problem of bad weather or food shortage in many cases by migrating to a more equitable climate where food is available. Before making the migration they become exceedingly fat; but when their long journey is ended the fat supply is practically consumed and they are often in an exhausted condition.

SOCIABILITY, COOPERATION, PROPERTY AND TERRITORIAL RIGHTS

Many animals are definitely gregarious and sociable; others lead solitary lives. Still others mingle with their kind for short periods of the year, but at other seasons prefer to be solitary. I believe it is probable that the requirements of an adequate food supply have much influence in determining whether animals must be solitary or may be gregarious. In many cases it is obvious that animals enjoy companionship with their own kind or even with animals of other species.

Particularly notable is the affection of the dog for man. This has probably been the great factor in leading to the dog's domestication.

Prairie dogs, which are not dogs at all but burrowing squirrels, are sociable fellows that live in colonies and visit back and forth from burrow to burrow. Indeed it is frequently difficult to ascertain who owns which burrow. I have observed, occasionally, if one prairie dog is in a position heading partially into a burrow and is obstructing the way of another who wants to get in, the one behind will pinch the tail of the traffic obstructor with his teeth. Apparently it is not a very hard pinch but it seems invariably to get results.

Recently I saw a young coypu or nutria, a large aquatic South American rodent, sitting on a log projecting out into the water. An adult was on the upper end of the log and wanted to go into the water. It induced the young one to make way for it by reaching down and gently but firmly pinching the young one's tail with its teeth. He also obtained action.

Among animals there are numerous instances of cooperation for the common good. A well-known example is the beaver colony in which several individuals cooperate in the building of the dam and house, and the storing of the winter supply of wood for food. They work together in perfect harmony and coordination.

The banding together of the wild African hunting dogs (*Lycaon pictus*), of the coyotes, and wolves (*Canis*), and, occasionally, of a few other animals that hunt prey too large to be taken by one individual, sometimes displays remarkable sagacity and cooperation. However, when the time for raising the young arrives, the packs usually break up into pairs, each of which selects a den some distance from the den of any others of its kind. Until the young are large enough to join the pack, the adults forage from their dens for small animals with which to feed their families.

Pelicans (*Pelecanus*) apparently cooperate in their fishing. They frequently swim on the surface of the water, several abreast and just far enough apart so that no bird will grab for a fish that is within the reach of another bird. When approaching a school of fish in such formation, the birds have an advantage in that each one can capture fish within its reach while the slowly advancing flock keeps the school of fish continually in front of it.

Those animals that live in groups probably all have some type of government or leadership. It is easy to see that each herd of bison is ruled by a dictator, the strongest bull of the group. Flocks of geese have a leader and give other evidences of government. The disciplining of offenders can often be witnessed. Usually the ruler of the herd or colony is also the sentinel who is on the lookout for danger while others feed. But it is doubtful if this is always the

case for apparently crows and other birds post more than one sentinel to watch for danger. If we could understand what is being said by crows in some of their gatherings, or by many other animals, we might learn of discussions and announcements that would surprise us. Certainly these gatherings have every appearance of definite meetings and discussions.

Some bats live in colonies and others live almost singly. With the exception of the fruit bats, those that live in colonies probably do so because of necessity arising from their habit of passing the daylight hours in caves or crevices, the supply of which is limited. When feeding, they travel widely through the air and work as individuals, probably with no serious competition in capturing their insect prey.

The fruit bats (family Pteropidae) live mainly in colonies that lead almost a nomadic life, shifting from one region to another to obtain an adequate supply of suitable food. Since there is usually enough food for all, they can live in large groups provided they go where fruit is plentiful.

The colonial habits of insects, wherein, as among the wasps, bees, and ants, numerous individuals work together to build a common house and to rear the young, form an apparently perfect community. The queen ant who lays the eggs but is helpless to defend herself is guarded continuously by others of her kind that bear scarcely any resemblance to her in appearance because they are remarkably modified for fighting. They are the soldiers of the group. The workers of the ant colony show no evidence of sexual characteristics but are specialized to do the labor for the community. Apparently they have rather definitely assigned duties. Some will forage for food and bring it home; others will attend to the growing of certain food supplies on which they may feed; others care for the young. Indeed there may be a far greater division of labor among the colony than is generally supposed.

The recognition of property and territorial rights among animals is clearly evident in many instances. This fact is well known among ornithologists, who have observed that most birds that do not nest in colonies select a nesting site and fight away other individuals of their own species for a rather definite area around the nest. The size of this area, of course, varies with different species, but is fairly constant for each species. This system is obviously based on the fact that any given area will, on the average, produce only a certain amount of food of the kind that is required by the occupants of the area. Therefore, if other pairs were permitted to invade the territory there would be too keen a competition for food. Frequently, other species are tolerated within the nesting area but this is ordinarily because the other species are sufficiently different in their food

requirements to cause no fear of competition. In this way, although a given area may appear to be indiscriminately occupied by many different kinds of birds, it is in reality more or less definitely divided into territories with fairly definite boundaries between pairs of individuals of each species. Naturally the boundaries do not coincide for the different species. Among the passerine birds the singing of the male of a pair is not merely an expression of happiness but is also a warning or notice to others of his kind that the territory in which he is singing is his own and that none should trespass on it. In the case of sea birds that nest in colonies but obtain their food from the ocean, the only territorial requirements of a nesting pair is that there be enough room for the adults and their nest. On the nesting site conflicts do not arise over food, because this is obtained in the ocean at a distance from the shore.

When certain mammals have established themselves on a given territory others appear to recognize, to some extent at least, the accompanying property right. We sometimes, for instance, see a small dog drive a larger, more powerful dog off the smaller dog's territory or away from its bone. Incidents of this kind can regularly be seen among other animals such as wolves, coyotes, foxes, squirrels, chipmunks, ground squirrels, and others.

VOICE AND COMMUNICATION

I have yet to become acquainted with an animal to which I feel that the term "dumb animal" should be applied. Animals are certainly not dumb as far as communication among themselves is concerned, and they must be fairly intelligent to have survived through the ages until man, the most dangerous and destructive of all creatures, began to kill them wantonly.

We are, of course, well acquainted with the voices of domestic dogs, cats, horses, cows, and other animals; but many creatures that are generally considered to be dumb actually have voices and use them regularly in communicating with their own kind.

"Bobbity," a tiny pocket mouse that lived on my desk at home for several years, appeared to be entirely silent. However, when I held him practically against my ear I found that he was carrying on a rapid chattering and scolding. Perhaps he understood my language and I was the dumb one because I did not understand his. A little female of the same species that was a temperamental spinster, had but to look at "Bobbity," change her expression ever so little, and he would be almost cowed. I am satisfied that she talked to him most effectively.

Kangaroo rats generally appear to be silent; but I have noticed that when two are brought together and do not desire to tolerate

each other, they utter a little buzzing growl. Also I noticed that a single one will give the same sort of a call when it is in the immediate presence of a grasshopper mouse, its mortal enemy in the wild. I have heard my pet kangaroo rat utter chirps that could be heard at a distance of 8 or 10 feet. If one of these animals is held close to one's ear a series of buzzing notes can be heard—dots and dashes in varying frequency and tempo—that must mean something to the creature that makes them. In their deep underground dens a distinct tapping of feet or tails can be heard from outside. These sounds evidently serve as means of communication between different nest chambers within the elaborate dwelling.

My pet grasshopper mouse calls, apparently to attract attention. These signals are most noticeable when the animal is running at liberty on my desk and my wife and I are in an adjoining room. At such times, he will choose a location from which he can watch us, then, rising on his hind legs, he will give an exceedingly high pitched piercing squeak that may be likened to a very high-pitched automobile brake squeak. The sound is of about one second duration. If I am about my desk he gives the call much less frequently, unless I appear to be paying no attention to him. The loudest of his calls can be heard by the ordinary human ear at a distance of perhaps 40 to 50 feet; but I have often seen him go through the motions of giving the call when the sound was so faint or high pitched that I could not hear it even when I was not more than 2 to 4 feet away from him.

Giraffes (*Camelopardalis*) are commonly thought to be voiceless. It has even been claimed that they possess no vocal cords. However, anatomists now say that they do possess poorly developed vocal cords; and there are authentic records that giraffes under extreme excitement utter a bleating call.

The emperor penguin (*Aptenodytes forsteri*), an Antarctic sea bird that was brought to the National Zoological Park in February 1940 from the United States Antarctic Exploration Expedition, greeted visitors in his cage by approaching them with his slow waddle. When about 5 or 6 feet away he would stop, bend his head far down on his breast and raise it gradually while he uttered a series of guttural musical notes somewhat like the cackle of a hen in point of timing but far deeper and more pleasing in quality. It appears probable that since the emperor penguin has practically no enemies on land or ice, he considers any other large object that approaches him as friendly. The emperor which stands about 40 inches high to the top of the head, is the tallest of the inhabitants of the Antarctic ice barrier.

Other means of communication are employed besides the voice. Many animals stamp the feet when danger threatens or when they meet an unknown condition that might prove to be dangerous. Deer (*Cervus* and *Odocoileus*) stamp their forefeet. The African brush-tailed porcupine (*Atherura*) stamps its hind feet. Sometimes there may be three or four strokes of the hind foot in quick succession, indicating irritation, displeasure, or warning. Skunks stamp both forefeet. Wood rats and kangaroo rats tap, tap, tap with their hind feet. Rabbits give warning by stamping their hind feet, and most people have witnessed a woman express her displeasure by tapping her toes. This foot-stamping is a telegraph warning that many animals heed.

In addition to the voices and the stamping of feet there is the buzzing sound produced by the rattle on the tail of the rattlesnake (*Crotalus*). Snakes that lack rattles vibrate their tails when excited. If the tail is touching dry vegetation a rattling sound is produced. Most porcupines vibrate their tails; some species have peculiarly modified hairs that make very effective rattles.

The visual telegraph is used by such animals as the American prong-horned antelope (*Antilocapra*) and the American elk or wapiti (*Cervus*). This is accomplished by erecting the hairs on the rumps of the animals. By raising these hairs from their normal flattened position until they stand almost on end, the light-colored bases of the hairs are made very conspicuous and readily seen by other members of the herd, who interpret them as a warning or signal flag. White-tailed deer also signal with erect tails. Because of this habit they are often called "flag-tails."

The booming of prairie chickens, hooting of blue grouse, and various nuptial calls of grouse and ptarmigan are all vocal sounds. The drumming of ruffed grouse (*Bonasa umbellus*) with their wings is a remarkably far-carrying sound made by the males during the mating season. The sharp "whirr" of the wings of a quail (*Colinus* and related genera) when taking flight is undoubtedly a warning to other members of the flock.

LOCOMOTION

The means by which most animals get about are so well known that detailed discussion of them here would not be justified, however interesting they might be as a subject of special study. In addition to the well-known modes of progression such as walking, running, hopping, flying, swimming, and crawling, some animals have developed special modes to meet their special requirements. Brief mention of some of these may be made here.

Bats are the only mammals that truly fly, although there are rodents in North America (*Glaucomys*), Africa (*Anomalurus* and *Idiurus*), and Asia (*Pteromys* and *Sciuropterus*) that are called "flying squirrels," marsupials (*Petaurus*) in Australia that are popularly known by the same name, and insectivores (*Galeopterus* and *Galeopithecus*) in the southern Asiatic regions that are usually called "flying lemurs." In reality these mammals do not actually fly: they merely glide. Their skins are a great deal larger than is necessary to envelop their bodies. On each side the skin is extended outward in a fold to the wrists, ankles, and hind feet. When the arms are spread forward and outward and the hind legs are spread backward and outward, the connecting skin is stretched so that the animal becomes greatly flattened and well adapted to gliding. The method is to climb to some fairly high point, leap off and coast downward through the air. Just before reaching the point at which it wishes to land, the animal turns upward so as to check its flight.

Bats, on the contrary, have true wings with a bone structure closely resembling that of our arms and hands. Their fingers are enormously elongated; and stretched between the fingers and the arm bones and extending back to the hind legs there is a thin, flexible fold of skin, which in some groups of bats crosses the space between the hind legs and includes part or all of the tail. With these remarkable wings bats really fly. Most bats rest and sleep hanging head downward suspended by their hind feet. Often the vertical surface on which the bat hangs appears to us to be practically smooth; but the small bats have such sharp little hooked claws on their hind feet that they can hang up on a roughness that we would scarcely detect. One that I had in my home regularly hung up on a wall that was covered with paper that was almost smooth. The method bats adopt to change from a condition of active flight to a perfectly quiet, restful position hanging head downward, is interesting. I have observed that some bats at least accomplish this by flying straight toward the wall until they are almost touching it, then turning upward until they do actually touch the wall, at the same time allowing themselves to fall sideways. Also, at the same time, the claws attach themselves to the wall. This is done so quickly that the human eye cannot follow the details of the animal's action. When in this position, hanging head downward, a bat is equally prepared to take off for another flight or to go to sleep.

The sea bears or eared seals, most commonly known as "sealions" (*Otaria* and *Zalophus*), and the fur seals (*Callorhinus*) have a fairly flexible body and long flippers. They hunch, sway, and flop along on a flat surface so that they are frequently able to travel some distance away from water on their bellies. Though greatly handicapped on land, they are so adept in swimming that when in the water they readily catch the fish on which they prey.

The earless, or hair, seals (*Phoca* and related genera) do not have such a flexible body as the sea bears, and their flippers are very short. They are perhaps as adept as the sea bears in the water, but when on land they can only progress by a peculiar bouncing movement that they bring about mainly by quickly contracting their bodies so that they actually bounce along with some aid given by their flippers.

Otters (*Lutra*) toboggan on their bellies on soft snow and steep earth slopes.

Penquins (*Aptenodytes*, *Pygoscelis*, *Spheniscus*) are especially adapted to a life in the water. However, they regularly go out on the shores and the Antarctic ice. Most of these shores are rocky, and the ice usually has abrupt walls rising out of the water, so that it would be very difficult for the birds to climb out as one might suppose they would have to do. But instead of climbing out in an awkward and inefficient manner, they actually spring out of the water. Coming with considerable speed up through the water, they leap on to the ice or land. As usually seen on such surfaces they are standing in almost a vertical position or slowly waddling along in a manner that to us seems ludicrous. However, they have evolved a remarkable means for escaping rapidly on the ice. They merely throw themselves on to their breasts, use their feet as propellers, dig their toes into the ice and snow, and toboggan rapidly along, even on level surfaces. Speeds estimated to be as much as 20 to 30 miles per hour have been observed. When swimming, penguins use their modified wings as oars. They steer with their feet.

The simile "like a fish out of water" is commonly used to indicate a very inefficient and unsatisfactory procedure. However, there are fish that are entirely at home out of water and that leave the water voluntarily to walk on exposed flats or dry land. Among these are the walking fish or climbing fish (*Anabas*) of southern Asia and Africa. When the impulse moves, these strange creatures climb up the bank out of the water, take a stroll on the ground and even climb into shrubs and trees. They really walk on the tips of their modified fins. In this way they make very satisfactory progress, individual fish being known to have traversed unhurriedly more than 300 feet in 30 minutes.[5]

Flying fish (*Exocoetus*) do not actually fly. They merely gain speed in the water, break through the surface into the air and glide with the aid of their large, winglike pectoral fins which serve as planes.

The young of certain large spiders and the adults of many smaller species make use of a novel type of aerial locomotion. They spin a

[5] Smith, Hugh M., A walking fish. Nat. Hist. (Amer.), vol. 37, pp. 249–252, March 1936.

long, gossamer thread that offers so much resistance to the wind and is so light that they can let go of their support, cling to their strand and be transported considerable distances by the breezes. They are, of course, unable to choose their direction other than as they may let go when the prevailing wind is in the direction that they desire to travel.

CARE OF YOUNG

Both the extent and the methods of caring for the young vary as widely as do other animal characteristics. No two species follow exactly the same methods. Some give painstaking individual care to their babies over long periods. Others look after the young for only a brief period until the precocious youngsters learn to shift for themselves. The rabbits are good examples of this second type. Still others give their young no care whatever.

The most primitive of the mammals, the platypus (*Ornithorhynchus*) of Australia and the so-called spiny anteaters (*Echidna* and *Zaglossus*) of Australia and Tasmania lay eggs. When the young are hatched they obtain the mother's milk by licking the skin on the surface of her chest, for these animals lack nipples.

The next higher group of mammals are the marsupials. Most marsupials have a very short gestation period and their young are born in a very incompletely developed state. The large kangaroos that stand as high as a man and weigh almost as much, give birth to young that weigh only a fraction of an ounce, after a gestation period of certainly less than 50 days and probably only about 20 or 30 days. The little one immediately after birth crawls into the abdominal pouch of the mother and remains there continuously for 3 or 4 months. After that, for a month or two, it spends a portion of its time in the pouch and a portion of its time moving about near its mother. If danger threatens, it quickly takes shelter in the pouch. Not all mammals that belong to the group known as marsupials have pouches. Those that lack the pouches give birth to young that are somewhat better developed than those of the pouched kinds. These young ones are cared for in a nest.

At the other extreme from the pouched mammals is the elephant, which has a gestation period of 18 to 21 months. The young elephant when born weighs about 220 pounds. It is carefully tended and nursed by its mother during a period that lasts from 2 to 3 years.

The monkeys also have a long gestation period. While the young at birth are fully formed they are almost as helpless as new-born human babies. They are carefully tended by their mothers for many months.

The female pronghorn antelope of western North America hides her baby on the prairie or on ground with very little vegetation by having it lie perfectly flat and still while she feeds or rests at a distance.

Musk oxen have adopted an excellent method of protecting their young from the wolves and bears of the region that they inhabit. They always go in small bands or herds, and when danger threatens, the adults form a complete ring, facing outward, with the young animals in the center of the ring. Thus, the charge of the pack of wolves can be met from any direction. This manner of defense was highly satisfactory for the preservation of the musk oxen until the coming of man, with his guns.

Most baby bats cling to the mother's nipple and to her fur while she flits about through the air or hangs up to sleep or rest. On some occasions, however, the mother leaves the little ones hanging in a safe place, goes on her flight, then comes back to it. The so-called naked bat (*Cheiromeles*) of Borneo carries her little one in a pocket formed by a fold of skin between her back, sides, and wing. Most bats have only one young at a time, although twins sometimes occur. In the North American red bat (*Nycteris*) and hoary bat (*Lasiurus*) there are occasionally triplets or quadruplets.

In the colder parts of the Northern Hemisphere baby bears (*Ursus*, *Euarctos*, and *Thalarctos*) are born while the mother is in hibernation, usually in February. New-born black bears weigh only about a pound, and the mother does not leave them for even a moment until springtime when she goes out to obtain food.

In moving her baby from one nest to another a squirrel (*Sciurus*) mother uses the following method. She turns the baby on its back and grasps one of its legs or the skin of its under parts in her teeth and lips, while the little one puts its forelegs around her neck from one side and its hind legs and tail from the other. In this way the baby is carried high enough so that its mother can use her feet in climbing and leaping, while at the same time, the little one helps to hold itself in place.

A mother polar bear (*Thalarctos*), when swimming, helps her baby along by letting it cling with its mouth to her tail or long hair. Thus she tows it along. When it is tired, she lets it ride on her back.

Gibbon (*Hylobates* and *Symphalangus*) babies cling beltlike around their mother's body. This leaves the mother free to use her arms and legs in swinging through the trees.

In addition to feeding and protecting the young, the parents of many kinds of mammals carefully lick their young ones to keep them clean until they learn to wash and groom their own coats.

Most birds incubate their eggs and care for their young, but the maleo fowl or mound-building bird (*Alectura* and related genera) of Australia, New Guinea, and the Philippines, have found a unique short-cut in incubating their eggs. The parents, using their feet and possibly their beaks, scratch together a mound of dead vegetation in the forest. Sometimes several pairs of birds will cooperate in the building of a mound as much as 30 feet long and 5 feet high. They then dig holes in the mound and lay their eggs in them. The heat generated by the decaying vegetation is sufficient to incubate the eggs. When the eggs hatch the young birds scratch their way to the surface and shift for themselves, never knowing their parents. The chicks are able to fly immediately on emerging from the mound.

On the other hand, there are many birds, such as the pelicans, that nest on barren rocky or sandy locations where the heat may be intense. They incubate their eggs when the temperature is not too high; but if the heat becomes too great they stand above the nest and shade it with their bodies.

Emperor penguins are large sea birds of the Antarctic region. They inhabit areas that are almost solid ice and snow with only occasional outcroppings of bare rock. Continuous darkness accompanied by intense cold and violent storms prevails for months at a time within the Antarctic Circle. Even in summer the weather conditions are not favorable for rearing families, and the best weather is of short duration. These penguins have, therefore, evolved a unique method of perpetuating their kind. Even if they laid their eggs very early in the springtime, the young would not be hatched until the summer was so far advanced that they would not have time to become well grown before the rigors of their first Antarctic winter set in. Therefore, the emperor penguins lay their single egg during the cold and darkness of the Antarctic night. They then incubate it by keeping the egg on their feet between their thighs so that it does not touch the ground, snow, or ice. The birds are so zealous in their care of the egg that male and female will at times actually fight to care for it. In this way, the egg is made to hatch in the Antarctic springtime so that the little one has the benefit of the full Antarctic summer during its tender period. By fall it will have become a husky youngster, ready to face the rigors of the Antarctic winter.

Some reptiles lay eggs that are hatched by the heat of the sun and the warmth of the sand or of decaying vegetation, the young ones never knowing their parents. Others give birth to living young. Apparently there is no clearly defined dividing line between the oviparous and viviparous groups of reptiles, for among nearly related horned lizards both types of reproduction are found. Some species

of this genus (*Phrynosoma*) lay eggs and others produce living young. In few cases, however, is there evidence that reptilian parents give their young care.

Some insects that do not actively care for their young after they have hatched make elaborate advance provision of food for the young that they will never see, and some, like the wasps and bees, have elaborate colony systems in which certain castes devote their time entirely to the care of the young.

Every animal that cares for its young has developed methods characteristically its own. Innumerable examples might be cited, did space permit.

LIFE WITHIN THE HOME

Naturally the life of an animal within its home is as specialized as are its activities outside. For example, the burrow of the pocket mouse is scarcely wider than the diameter of the animal's body. One may well wonder how it is possible to turn about in one of them; but my little pet showed me how this is done. I found that when he wanted to reverse his direction and the burrow was too small to allow him to turn in it, he tucked his head backward beneath his body and practically revolved on himself like a ball. This brought him wrongside up; but, too quickly for the eye to see the detail of his movements, he would roll over and be ready to go in the opposite direction.

The tunnel of the mole is only slightly greater in diameter than the body of the animal. Therefore, turning about would be a problem, particularly as the forward two-thirds of the mole's body is extremely rigid and muscular. To avoid turning around the mole merely runs backward in his burrow. This he can do about as fast as he can go forward. If the mole's fur were even fairly stiff and its hairs were directed backward, it would impede the animal's backward progression; but it is very short with the hairs standing at right angles to the skin so that they will lie smoothly when pointing either forward or backward.

In their nest chamber beavers groom themselves, eat the pieces of wood that they carry up into the houses through the tunnels, sleep, raise their young, and remain secure from enemies.

CLEANLINESS AND CARE OF THE BODY COVERING

Human beings replenish their wardrobes as required or as their means permit. Animals, however, are limited to definite times for getting their new suits of clothes. Usually they grow a heavy coat with the approach of winter. This coat lasts them until spring, by which time it has become considerably worn. It is then shed

and replaced with a lighter coat better adapted for summer wear. If animals did not give enough care to their clothes, they might be left in a precarious condition between seasons. In fact, they might have "nothing to wear." Therefore, each species has developed a very definite technique for the care of its clothing.

Upon awaking at their leisure nearly all animals go through more or less the same procedure as human beings. They yawn, stretch, and the furry creatures proceed to groom their coats and straighten their whiskers painstakingly. Indeed, all furry and feathered creatures take good care of their clothes—a fact evidently recognized by the composer of the song, current in the early 1900's, that referred to a raccoon as "combing her hair by the light of the silvery moon."

As animals travel through shrubbery and grass their coats are brushed and the shedding of the old hair is especially aided. The wear incidental to such passage through coarse grasses is very noticeable in lions, the wild individuals rarely having as fine manes as those grown by captives.

Most people are familiar with the house cat's very careful licking of itself for cleanliness and to keep its fur in good condition.

The horse that rolls, particularly when his harness has just been removed, is using one means of loosening and straightening his hair. In the springtime, it is a common sight to see two horses standing side by side faced in opposite directions each using its lips and teeth to pluck the heavy winter coat off of his companion. Even the ungainly bison (*Bison*) roll. Bears just out of hibernation rub vigorously against trees and rocks and quickly remove great patches of hair so that they sometimes become exceedingly ragged and for a short time almost naked.

Some animals enjoy bathing and if one will observe such a creature taking a bath after having been deprived of the opportunity for some time, he will witness enjoyment as great as any person could display in enjoying a long-deferred bath.

Desert mammals that rarely have access to water abhor it and are greatly offended by even a drop that may get on them; but they have evolved a method of keeping their fur in good condition by rolling in fine dry sand. This is not an aimless process; the movement is so definite that it partially combs the fur without mussing it up. They then shake themselves and carefully comb their fur with the tiny nails on their hands and feet, assisted in some cases by their teeth and lips. Perhaps in some cases there is a slight licking of the fur; but more often the cleaning process appears to be nothing more than smoothing the fur or freeing it of tangles. In grooming the tail, almost all begin at the base and work

outward until the full length of the tail has passed through the lips and hands. The whiskers are very important organs of touch. Therefore, they are often straightened and adjusted. The skins of desert animals secrete considerable oil for their fur. This is shown by the fact that the hairs stick together and the coat becomes very unsightly if the little creatures do not have access to sand for a day or two.

Many people who have seen little furry creatures scratching themselves have assumed that this action indicates infestation by fleas or other parasites. However, most animals are very clean and have relatively few external parasites. Some have apparently learned that tobacco is an excellent insecticide. I recently discovered that my pet grasshopper mouse would chew up bits of tobacco, then open his fur with his hands and place the chewed tobacco in his fur close to his skin. This was plainly the application of tobacco to spots that were itchy. In this particular case the animal had been so well supplied with insect powder that he had no external parasites. He apparently did not distinguish between the normal itchiness to which little furry creatures are subject and the external parasites that would be killed by tobacco.

Semiaquatic animals like the beaver wear coats that are composed of two important layers—the long coarse guard hairs (that give the coat its rough appearance) and the very dense coat of fine silky short under hair which insulates the animal and is, if well cared for, impervious to water. Proper care of the coat is of great importance to the beaver. Almost immediately after coming out of the water, he will begin a painstaking grooming by which he will wipe or rub off most of the surplus water. Then he will proceed to comb out the fur until it is dry and loose. It has been found that if beavers and some other animals cannot groom their fur and dry it out they become very susceptible to pneumonia and related ailments.

It is a common sight to see monkeys carefully grooming each other's fur. Most visitors to the Zoo mistakenly believe that this activity is a search for parasites. But, as a matter of fact, parasites are so extremely rare on monkeys that their presence can in no way account for the grooming habit. Grooming is apparently an enjoyable process of cleaning the fur and skin. It probably finds its exact counterpart among human beings in the pleasure most people take in having their backs scratched and in the soothing, almost hypnotic effect of the treatment received in beauty parlors and barber shops.[6]

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[6] Grooming by animals is more than a mere dressing of the coat. It has a definite part in the social lives of the animals. Considerable has been written on this subject, one paper being "Sham louse-picking, or grooming among monkeys," by H. E. Ewing, Journ. Mamm., vol. 16, pp. 303–306, November 1935.

Some monkeys have even gone farther and supplemented their grooming with a very definite system of hair plucking. This habit is especially well developed in the Japanese macaque. In this animal the hair grows fairly long on the sides of the head as well as on the crown. Some individuals have developed a system of plucking the hair around the sides of their companions' heads so as to give almost the effect of a human hair cut. The hair on the crown is left undisturbed. This plucking is not a hit-and-miss affair, it is very systematic and symmetrical, giving the animals the appearance of having been carefuly groomed. (See pl. 15, fig 1.) One individual that I have observed, that lives alone, plucks the hair on his own forearm.

There are members of our medical profession and many other individuals who feel that the human body derives a very definite benefit from close contact with the earth. By the nature of their lives, animals are more constantly in contact with the earth than are human beings. When we observe the true enjoyment that pigs, rhinoceroses, elephants, and numerous other animals derive from wallowing in the mud, can we doubt that they get some very definite benefit from this habit? The skins of wallowing mammals being practically bare are especially subject to drying and to the bites of insects. Therefore, mud baths must be soothing if nothing more.

Many birds will bathe whenever water is available even though it be ice cold. Following such a bath, they have a bedraggled appearance but if one will observe them, he will see that they vigorously shake their plumage and preen it until the feathers are fluffed out and in good condition. Indeed, in many instances, if birds cannot bathe, their plumage becomes unsightly and they themselves appear to become discontented and uncomfortable. Birds also shake themselves and fluff out and arrange their feathers. Chickens dusting in the road or elsewhere, then shaking their feathers and cleaning them, are familiar examples of this habit. Even flies and other insects groom themselves after having eaten or having become soiled. Innumerable other instances might be mentioned.

MEMORY

Memory is a faculty that we ascribe mainly to human beings; but most animals obviously remember things that concern them. Naturally the things that make the greatest impression on animals are those that relate to avoidance of their enemies, the finding of their home and food, and other activities essential to their welfare. The term "homing instinct" has been applied to the pronounced ability of certain animals, noticeably cats and carrier pigeons, to find their way back to their homes. However, it is even more pronounced in the birds that migrate many hundreds of miles and find their way

back the next year to the exact spot that they started from the year before. We know practically nothing as to what guides birds and mammals on these long migrations; but we can readily observe in many animals the painstaking investigation that they make of their surroundings, obviously with the intention of familiarizing themselves with their immediate environs.

A pet kangaroo rat that was given the run of our apartment for a period of about 2 weeks selected the space beneath the mechanical refrigerator for her abode. Whenever she thought danger threatened she would immediately retreat there. At other times she would explore around the apartment. If we remained quiet she would venture close to us. After about 2 weeks of this freedom she was kept in a cage from which she was occasionally removed for little outings; however, she did not have another opportunity to utilize the space beneath the refrigerator. But one day about a year later, when she was again left free on the floor, she made persistent efforts to get into the kitchen where the refrigerator was located, thus obviously showing that her memory of the home she formerly used had remained with her for at least a year.

USES OF HANDS, FEET, TAILS, AND TEETH

As "necessity is the mother of invention," it has naturally led animals to utilize their hands, feet, tails, and teeth in many effective ways. The tails of horses, cattle, and a number of other animals are valuable in dislodging insect pests. In other mammals, such as the kangaroos (*Macropus*) and the jumping rodents, it is important as a balancing organ and is sometimes used as a spare hind leg to make a tripod to sit on. With the Old World monkeys the tail appears to be largely an ornament, although it is useful in helping the animals to keep their balance when leaping. Among the cats it is useful for the expression of emotions; and it also assists the animals in righting and balancing themselves when leaping or falling. Those cats that have long and fairly bushy tails use them as muffs to help keep their feet and noses warm.

The binturongs (*Arctictis*) of the southern Asiatic region and the pangolins (*Manis*, *Smutsia*, and related genera) of southern Asia and Africa, also the North American opossum, the South American porcupines (*Coendou*), and a few other animals use the tail mainly to steady themselves by wrapping it around a limb, or to let themselves down gradually when descending. Some of the American monkeys use the tail regularly in this manner, the most noteworthy of these animals being the spider monkeys (*Ateles*). The underside of the tip of the spider monkey's tail is naked like a fingertip. This makes it a good grasping organ. If an object is beyond the reach of the very long

arms of a spider monkey, the animal will sometimes back up as near to it as possible, then reach out and grasp it with the tail tip.

A good example of the manner in which the tail is useful as a balancing organ or to check the animal when it is leaping is shown in the picture of the douroucouli or night monkey (*Aotus*) of the Central American region (pl. 16). On a few occasions I had noticed that when these monkeys leaped onto a limb their tails swung forward under the limb. However, the movement was so quick that I could never be quite certain of the position the tail assumed. I could only surmise that it was used to balance the animal. When I took this picture I was trying to photograph the monkey that is shown at the right, but apparently an instant before I made the flash the monkey at the left leaped onto the limb and checked his forward movement by swinging his tail under the limb. His arrival caused the monkey on the right to turn its head so quickly during the $\frac{1}{500}$-second exposure that its face was slightly blurred.

The pangolin uses its tail to wrap about itself to keep out enemies.

The tails of whales and porpoises are the propellers that drive these animals through the water. They work in a vertical plane instead of horizontally like the tails of most fishes.

The hands of gibbons and orangutans (*Pongo*) are long and slender with the very small thumb placed far back. Thus, the hands are better adapted to be used as flexible hooks than as grasping organs. During their lives in the trees these animals use their hands in this manner—that is, by hooking them over the limbs. This is of great advantage to the gibbons in their flightlike swinging through the trees.

The feet of the gibbons, orangutans, and chimpanzees (*Pan*) are fairly well adapted for grasping, the great toe being opposable to the other toes. This permits them to use their feet in grasping limbs or in carrying objects while they use their hands in swinging through the trees. On one occasion I saw a young chimpanzee trying to carry away all of its food at one trip. It had both its hands full and half a head of lettuce grasped in one foot.

The loosening and moving of earth, and in some cases the packing of earth, plays so important a part in the lives of many animals that they have developed considerable efficiency in the task. Most burrowing animals do their digging with the forefeet, which are generally rather large and are armed with short, straight, or slightly curved claws well adapted for use as picks. They generally pull the earth toward them and underneath them to a point where it can be reached by the hind feet. These kick it backward. If they are working inside a burrow they generally turn around and go toward the entrance pushing the loosened earth before them, using their front feet together with their chests and throats as pushers while the hind feet supply the

power. Badgers (*Taxidea*) probably surpass other mammals in the quantity of earth they excavate in digging out their prey.

The little desert creatures such as the pocket mice and kangaroo rats pack the sand about their houses with their forefeet, patting it so rapidly that a buzzing sound is produced; but the motions are too rapid to enable the human eye to catch the details.

The teeth of rodents protrude considerably, and are important for cutting wood, as weapons of defense, and as tools for digging. Often the burrowing rodent uses his teeth to remove stones or to cut hard earth. The lips of certain groups are closed behind the large front incisors so that the front teeth actually protrude outside of the mouth proper. Thus, dirt is kept out of the mouth by the lips which make curtains or doors close behind the teeth. The mouths of rodents are situated rather definitely on the underside of the head in a position well adapted for working below the level of the nose. They would thus appear to be poorly adapted for working above that level. These animals have, however, effectively solved the problem of cutting out the top of a tunnel or cutting a root or other object obstructing the upper portion of a runway. They merely throw themselves on their backs and hold the underside of their heads close to the top of the burrow so that they can cut upward as easily as downward.

USE OF TOOLS AND MATERIALS

The use of tools and materials is more common among animals than is generally supposed. The best known use of materials is seen in the making of birds' nests. In this work each species of bird follows a very definite pattern of procedure. Many birds choose a special kind of material for one part of the nest, and a different type of material for another part of it.

Among mammals the making of the nest, particularly the lining of a cavity with material that is dry and insulating, is well known. It is common to see squirrels carrying dry leaves or shredded bark to their homes, particularly after an unusually cold night or a bad rain. Apparently the little fellows have not been comfortable through the night and their first thought in the morning is to improve their nest.

The habit of the so-called pack rat or trade rat (*Neotoma* and *Teonoma*) of carrying small articles away from a camp and leaving something in place of the objects taken has been frequently described. Apparently the rodent's idea is to carry material to its home for protection against invasion, or perhaps for ornamentation. For example, a nest in a crevice of a cliff or at the base of a cliff may not provide adequate protection on the exposed sides. Therefore the clever rodent carries sticks, dried cow dung, dried cactus pads, and

other things to fill portions of the crevices or to build a mound at the base of the cliff in order that it may make its nest under a protective covering. It is remarkable how many of the exceedingly spiny dried prickly pear joints they will use when such material is available. Often the nest is composed chiefly of these joints, which are indeed excellent protection against enemies. Certainly we cannot doubt that the pack rat is well aware of their value. With regard to the pack rats' propensity for carrying a shining object away from a camp and leaving something in its place, it is my theory that the animals are usually carrying something, and that when they find the bright object that they prefer they drop the one they have been carrying and pick up the one that is more to their liking.

In building their dams or their houses, beavers have need to use considerable earth that sometimes must be transported over distances of several feet or even rods. One method of carrying it is to gather a mass in their hands held against their breasts while they walk or swim to the place where the earth is needed. In this manner they move a surprising amount of earth. In addition to earth, sticks and occasionally stones are regularly used by beavers in the building of dams.

Wasps and ants have been observed picking up small pebbles in their jaws and using them to tamp the earth. Wasps have been observed to take a small twig and sweep or smooth the ground over their burrow which they had just filled. These are a few known instances of the use of tools by some of the lower animals.

Occasionally individual monkeys adopt the practice of throwing objects at a fancied enemy. However, this is not a general practice among monkeys despite the popular belief to the contrary. The practice of natives of southern Asia and the East Indies of sending monkeys up coconut trees to break off the nuts is often cited as evidence that monkeys do throw objects at adversaries. In reality the monkeys, usually pig-tailed macaques (*Macaca nemestrina*), are carefully trained to go up coconut trees, twist off the ripe coconuts by twirling them between their hind feet, and let them fall on the ground.

I once saw an orangutan grasp a handful of more or less parallel straws in both hands, held about 20 inches apart. The animal then looped his rude straw rope over a projecting iron pipe and swung from it.

EFFICIENCY

Modern mankind lays stress on skill and efficiency. Evidently animals do likewise, for careful observation of the ways in which they carry out the everyday practices of their lives indicates that they are surprisingly efficient in all their actions. Perhaps if it were

possible to calculate the average efficiency of any given species we might see that any one of the lower animals is as efficient as man in fulfilling its particular functions in this world. Close study of animals will often disclose that movements which at first glance we might consider aimless, are, in reality, following a very definite pattern, evidently with a definite purpose. For example, if a plot of land be dug up or otherwise disturbed, squirrels will go over it painstakingly, investigating almost every square inch. I believe that the animals are familiarizing themselves with the area in its changed condition so that they may intimately know all of the ground that constitutes their range. Obviously, when it becomes necessary for one of them to flee to save his life he must know exactly where safety can be found. A little study along these lines will indicate that every animal knows its territory intimately. The liberation of an animal in new surroundings invariably leads to a most painstaking examination of those surroundings. Usually the animal will at first stand perfectly still and look about, sniffing and frequently testing the objects near it with its nose, teeth, and paws. It will then gradually explore farther and farther. If it is forced to attempt to make a sudden escape before it has become thoroughly familiar with new surroundings, it will often make bad mistakes. For example, if it is liberated in a fenced enclosure, it will sometimes run headlong into the fence so hard as to kill or cripple itself or it will dash into water and make other like blunders.

A British Army officer who had a pet mongoose that traveled with him in India observed that every evening when camp was made and the mongoose was liberated, it made a painstaking examination of the tent and all objects in the tent and its surroundings. He reached the conclusion that such an examination was necessary to enable the animal to know exactly where to go in the event of an emergency.

We often marvel at the way animals appear to travel with such certainty in the dark. Our first thought on observing this phenomenon is that the creatures can see. However, we know that, guided by the sense of touch, they get about readily in absolute darkness where sight is impossible. Usually they are traversing ground on which they grew up and with every portion of which they are thoroughly familiar. Furthermore, I have observed that the small creatures extend their very long whiskers forward and to each side to the utmost that they can be extended, just as a person in a dark room keeps one hand out at the side to maintain contact with the wall and keeps the other hand directly in front in order to be given warning by touching objects with his finger tips. This is exactly the procedure that is followed by many little nocturnal creatures. While they can undoubtedly see far better in subdued light than we can, there is no

reason to suppose that they can see in the total darkness prevailing in their burrows and in many places that they regularly frequent. They become accustomed to following a wall or the base of a tree; and their whiskers tell them that they are keeping just a whisker's length away from it. If a change in the surroundings has been made while they were away, they at once detect it, or if an object has been placed in the path and their forward-extended whiskers touch it, they have such control of their movements that, ordinarily, they will stop or turn before they actually hit the object. Furthermore, they have such exceptional powers of scent that they may be able to detect the newly placed object or the disturbed condition before they come in contact with it. Possibly they may even know by counting a given number of steps that they have traversed a given distance in a certain direction and that the time has come to change their course.

The fact that any species of animal has survived the numerous hazards that have beset its kind down through the ages shows that it must have become efficient enough in its mode of life to have escaped destruction by famines, floods, droughts, diseases, fires, and predatory animals. We know from the records of the great number of animals now found as fossils that many species were not able to survive. Sometimes the geologists and paleontologists have been able to reach a conclusion as to why these species became extinct; in other instances they are still at a loss for an explanation. It is obvious, however, that the animals living today are descended from ancestors that were able to cope, through the ages, with nature's great array of hazards and problems; in other words that the efficient ones survived and the inefficient ones succumbed.

PLAY AND EXERCISE

Most people have, of course, witnessed the play of kittens and puppies and that of some other young animals. But play is not limited to the very young of only a few kinds. It is obviously enjoyed by so many different creatures that there can be no doubt that practically all animals play. Young carnivores when playing with others of their kind learn how to stalk, attack, and overpower their prey. This can easily be witnessed by watching kittens at play. Squirrels, even adults, plainly engage in play when they chase each other about and obviously have grand times.

I have often noticed that my pet grasshopper mouse, "Ony," which has freedom on my desk almost every evening, frequently will make unnecessary movements that plainly show his exuberantly good spirits. By flipping a piece of string at him I induce him to play with the string and pull at it much as a dog pulls at a rope.

In the zoo, we place either the inclined disk-type or the ferris-type exercise wheels in cages of many of the smaller animals so that they may have an opportunity to exercise. Many of the more active animals use these wheels and plainly enjoy them. Some of our keepers have observed that when small exercise wheels have been standing where the wild house mice could get at them they would run the wheels even though they were entirely free to come and go about the premises as they pleased.

A little pocket mouse now living in my study at home runs her wheel almost continuously from about 9 p. m. to 7 a. m. "Ony," the grasshopper mouse that also lives in my study, does not run his wheel so constantly, but he uses it at frequent intervals from about 10 p. m. to 6 a. m. Each wheel has a characteristic sound that I can hear in my bedroom; thus I am kept well informed of my pets' activities.

Vernon Bailey, for many years Chief Field Naturalist of the United States Biological Survey, has informed me that he has found that some of the animals in the wild state, particularly kangaroo rats, would run disk-type wheels placed near their burrows.

CONCLUSION

All persons who have kept pets have probably bored their friends by telling them of the interesting and clever behavior of these animals, and no doubt most people have thought that their pets were behaving in an unusual manner and that they were exceptions to the rule. This is undoubtedly true in some cases where the pets have had exceptional educational advantages in homes where they were treated almost as one of the family; but we should bear in mind that animals' reactions to the new conditions with which they may be surrounded are the product of the age-long efforts of the species to adapt itself to its surroundings, and that the individual confronted with new conditions must meet those conditions to the best of his ability based on the instincts of the species and his own intelligence.

Almost every dog owner has seen his pet do many things that seem to him to indicate unusual intelligence on the animal's part. Generally the acts that he has observed do show intelligence, but they are not isolated instances. They are merely isolated cases of a man's observing and in part comprehending some of the things that animals can regularly do.

Any species of mammal, bird, reptile, amphibian, fish, insect, or other form of animal life that has survived the vicissitudes of the ages has developed technique that is well adapted to the perpetuation of the species. But the student will regularly encounter actions that he is unable to explain. He may, however, feel certain that such actions are not haphazard but that they are very definitely associated

with some need through which the species has passed. It may be that the reaction is no longer of great importance, because conditions have changed since it was developed. But it is safe to assume that at one time it served a very definite purpose.

It is not necessary for the purposes of this paper that we try to decide which of the reactions are prompted by instinct and which are the result of intelligence and thought on the part of the individual.

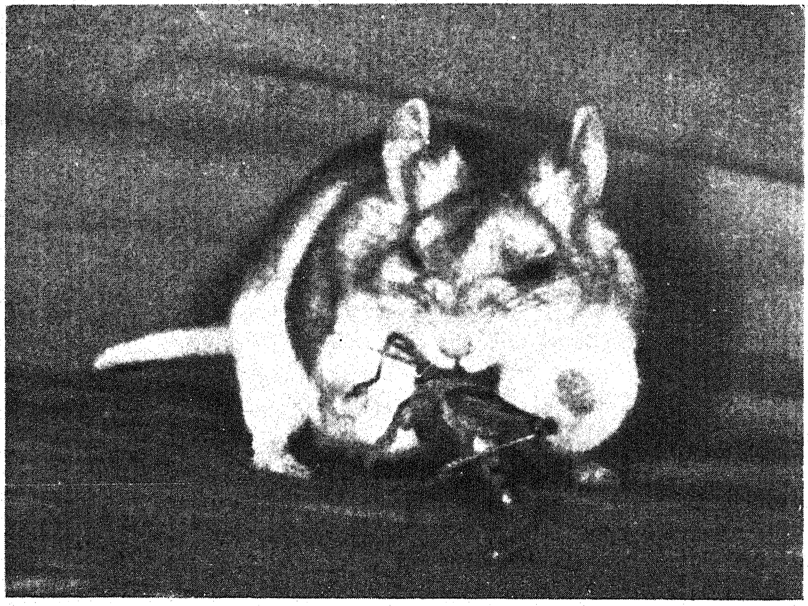
But in observing great numbers of animals in conditions entirely new to them, one cannot help reaching the conclusion that animals must do considerable thinking. Indeed, it has been my observation that the more one knows of animals the more he is likely to give them credit for powers of thought.

Of the great number of questions asked me regarding animals, only two do I find irritating. These are "What is it good for, or is it good to eat?" and "Is it mean?" While we frequently cannot point out acts or behavior of animals that are definitely beneficial to us, we are constantly finding as we learn more about animals that every one of them must have its definite function in the economy of nature. While forms of life may be harmful to some of man's activities, it is doubtful if the welfare of the world in general would be much advanced by the total extermination of any creature.

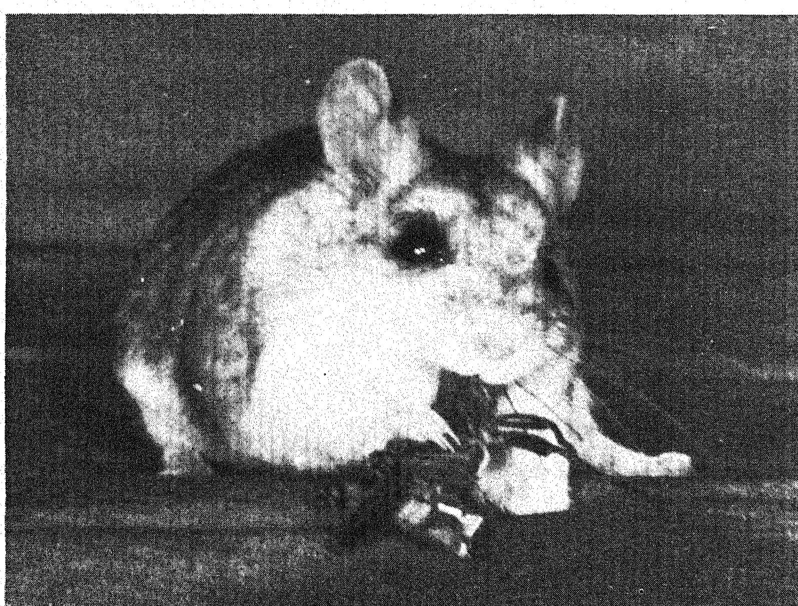
In general, the sole interest of animals is to make their living and avoid conflict. Almost invariably, if they have the opportunity, they will avoid encounters with man.

1. A WELL-ARMORED AFRICAN HEDGEHOG (ATELERIX HINDEI).
Photograph by Ernest P. Walker.

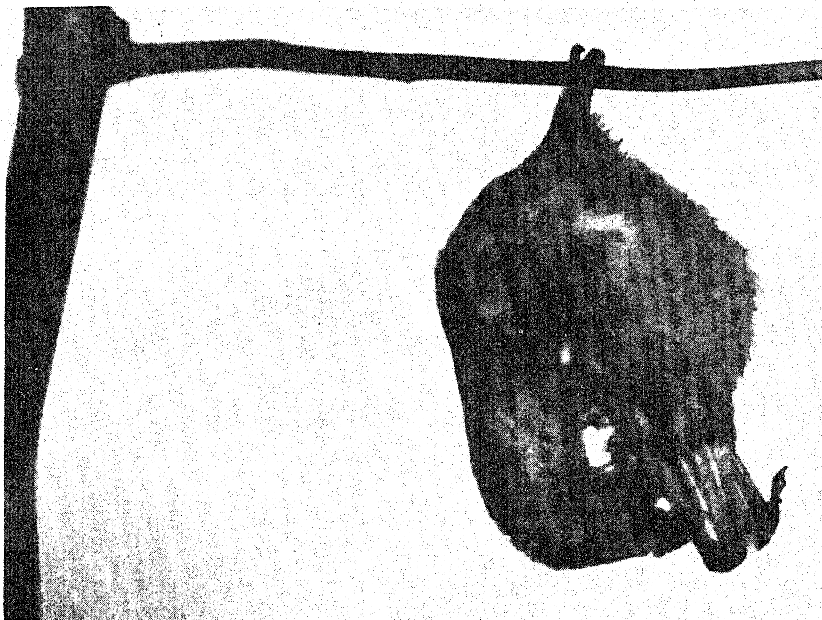
2. AFRICAN HEDGEHOG PARTIALLY ROLLED UP.
Photograph by Ernest P. Walker.



1. "ONY," GRASSHOPPER MOUSE (ONYCHOMYS LEUCOGASTER), KILLING A GRASSHOPPER AND KEEPING HIS EYES CLOSED DURING THE CONFLICT.
Photograph by Ernest P. Walker.

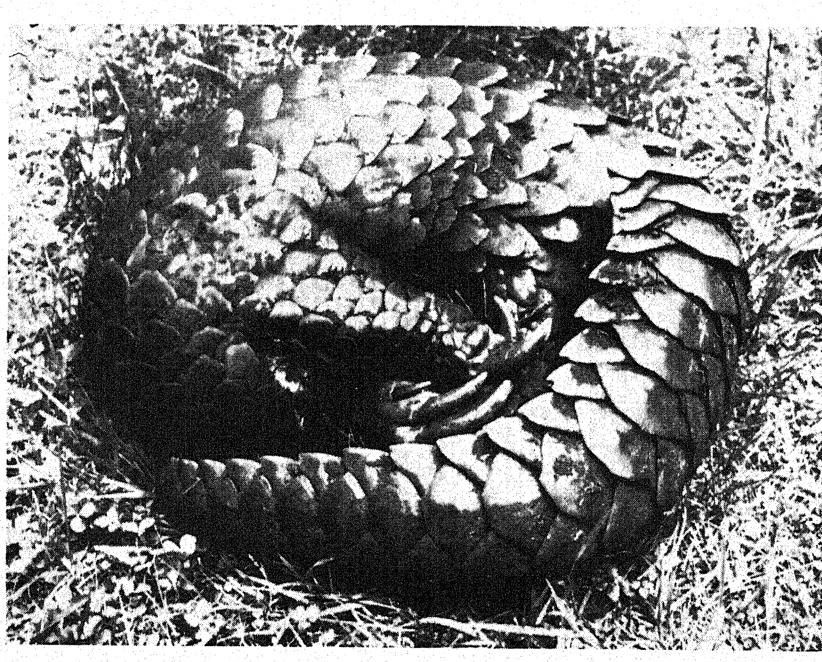


2. "ONY," AFTER KILLING THE GRASSHOPPER, HAS HIS EYES OPEN.
Photograph by Ernest P. Walker.



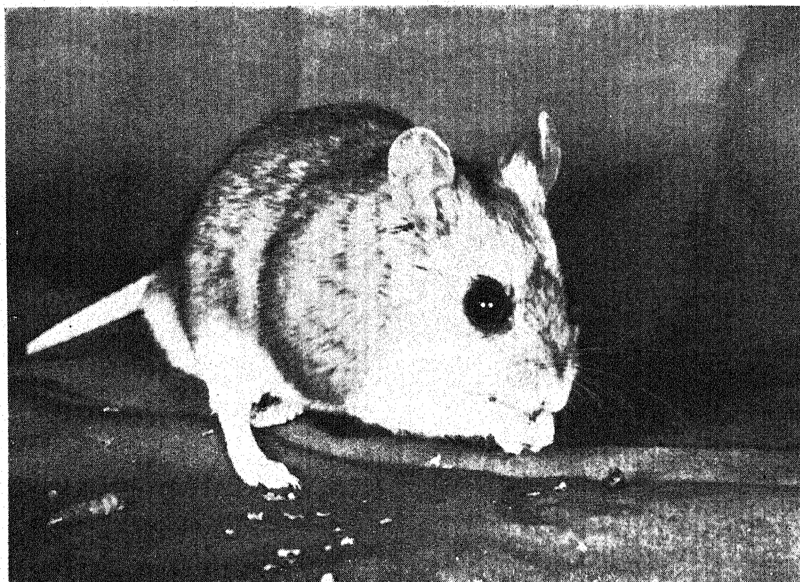
1. NORTHERN RED BAT (NYCTERIS BOREALIS).

A solitary tree-hanging North American species hanging by its right hind foot. The membrane between the legs and tail is spread downward over the under parts and hides most of the folded wings beneath which the head is hidden. Photograph by Ernest P. Walker.



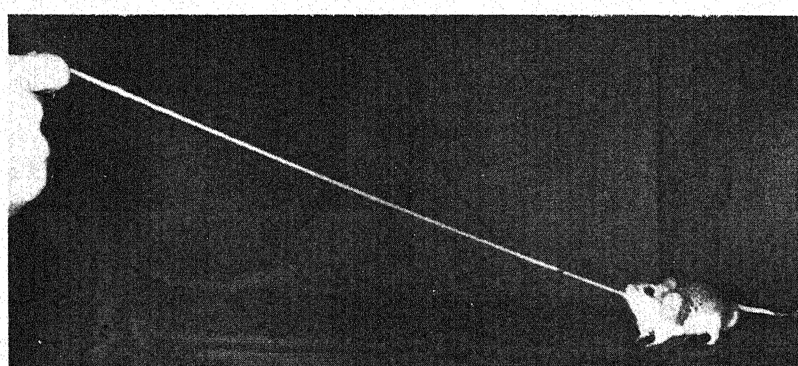
2. GIANT PANGOLIN (SMUTSIA) OF WESTERN AFRICA.

A scaly mammal loosely coiled in somewhat the position it assumes when attacked. Photograph by Ernest P. Walker.



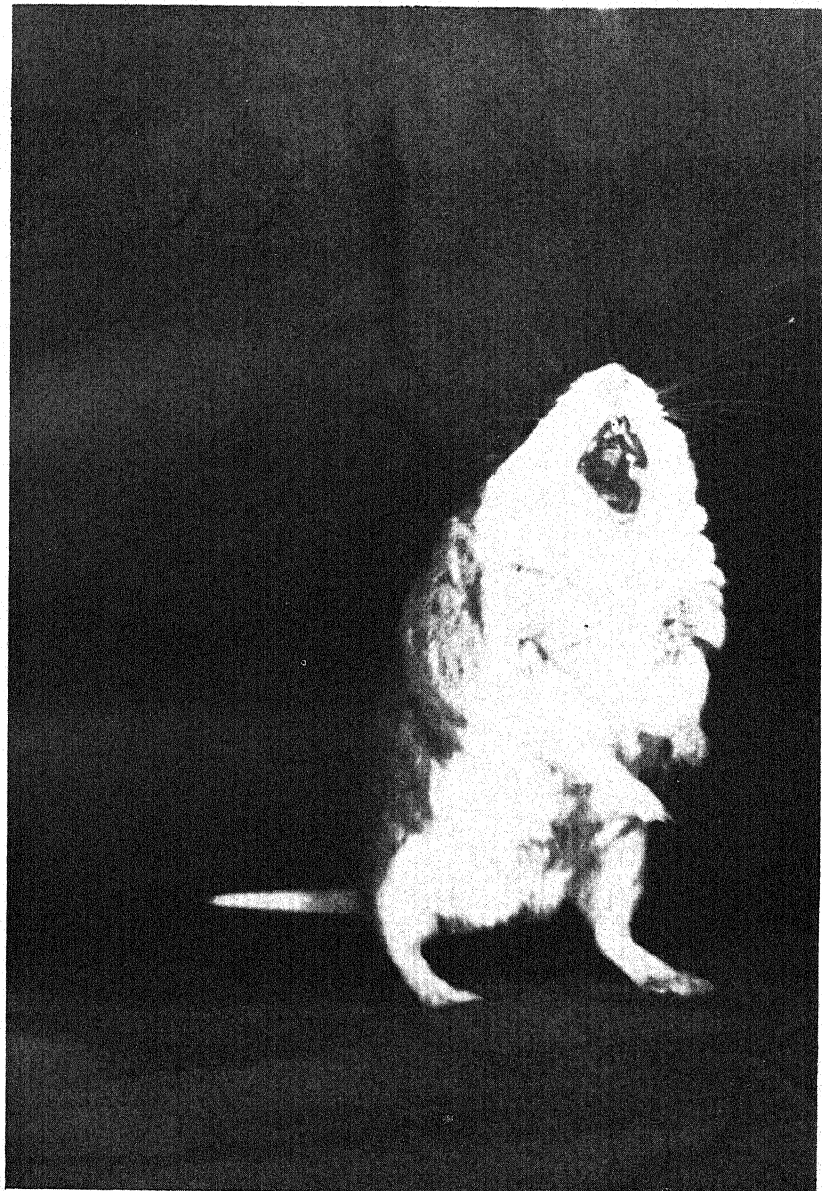
1. "ONY" HOLDS A MEALWORM IN BOTH HANDS WHILE EATING IT, SITTING ON HIS HAUNCHES.

Photograph by Ernest P. Walker.

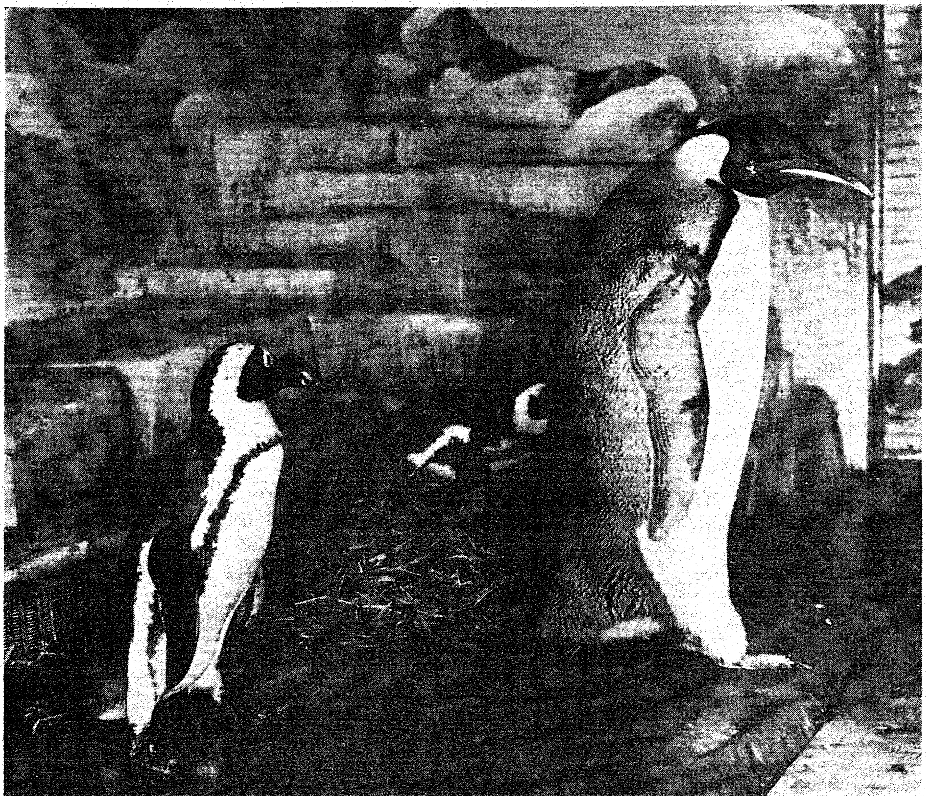


2. "ONY" PULLS AT A STRING IN THE AUTHOR'S HAND, JUST AS DOGS AND CATS WILL PULL AT STRINGS OR ROPES.

Photograph by Ernest P. Walker.

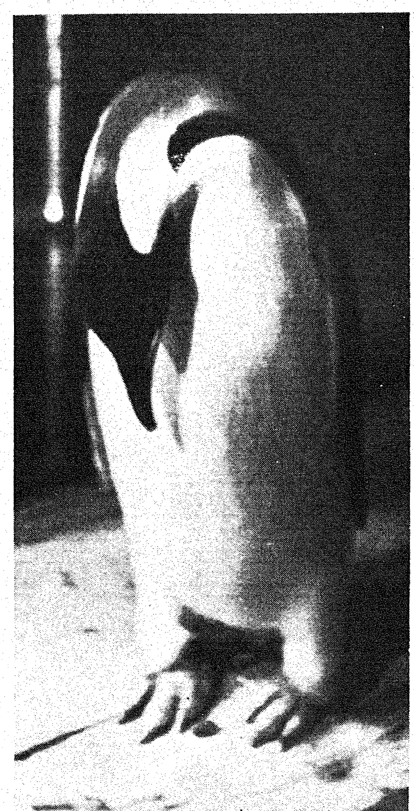


"ONY" CALLING.
Photograph by Ernest P. Walker.



1. EMPEROR PENGUIN (APTENODYTES FORSTERI) AND JACKASS PENGUINS (SPHENISCUS DEMERSUS) IN THE REFRIGERATED ROOM IN THE NATIONAL ZOOLOGICAL PARK, WASHINGTON, D. C.

The wings are modified for swimming and the feathers are scalelike. Photograph by Ernest P. Walker.



2. EMPEROR PENGUIN IN THE POSITION IT ASSUMES WHEN GIVING ITS GREETING CALL.

Photograph by Ernest P. Walker.

1. A NORTH AMERICAN "FLYING SQUIRREL" (GLAUCOMYS VOLANS) YAWNING AND STRETCHING.

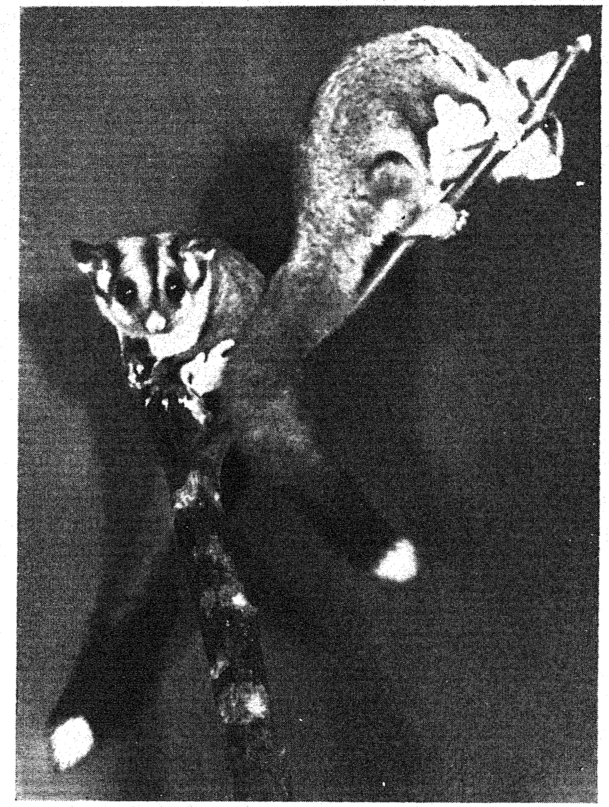
The edge of the membrane that stretches from its left wrist to its left ankle is clearly shown by the white line. Photograph by Ernest P. Walker.

2. BINTURONG (ARCTICTIS BINTURONG), A PREHENSILE-TAILED CARNIVORE.

One of several Malayan carnivores that have adopted a diet of fruit and vegetable matter. Photograph by Ernest P. Walker.

1. VULPINE OPOSSUM (TRICHOSURUS VULPECULA), A NATIVE OF AUSTRALIA.

The tip and under portion of the terminal third of the tail are naked to give a better grasp when it is used in climbing. Photograph by Ernest P. Walker.



2. AUSTRALIAN "FLYING OPOSSUMS OR PHALANGERS" (PETAURUS BREVICEPS).

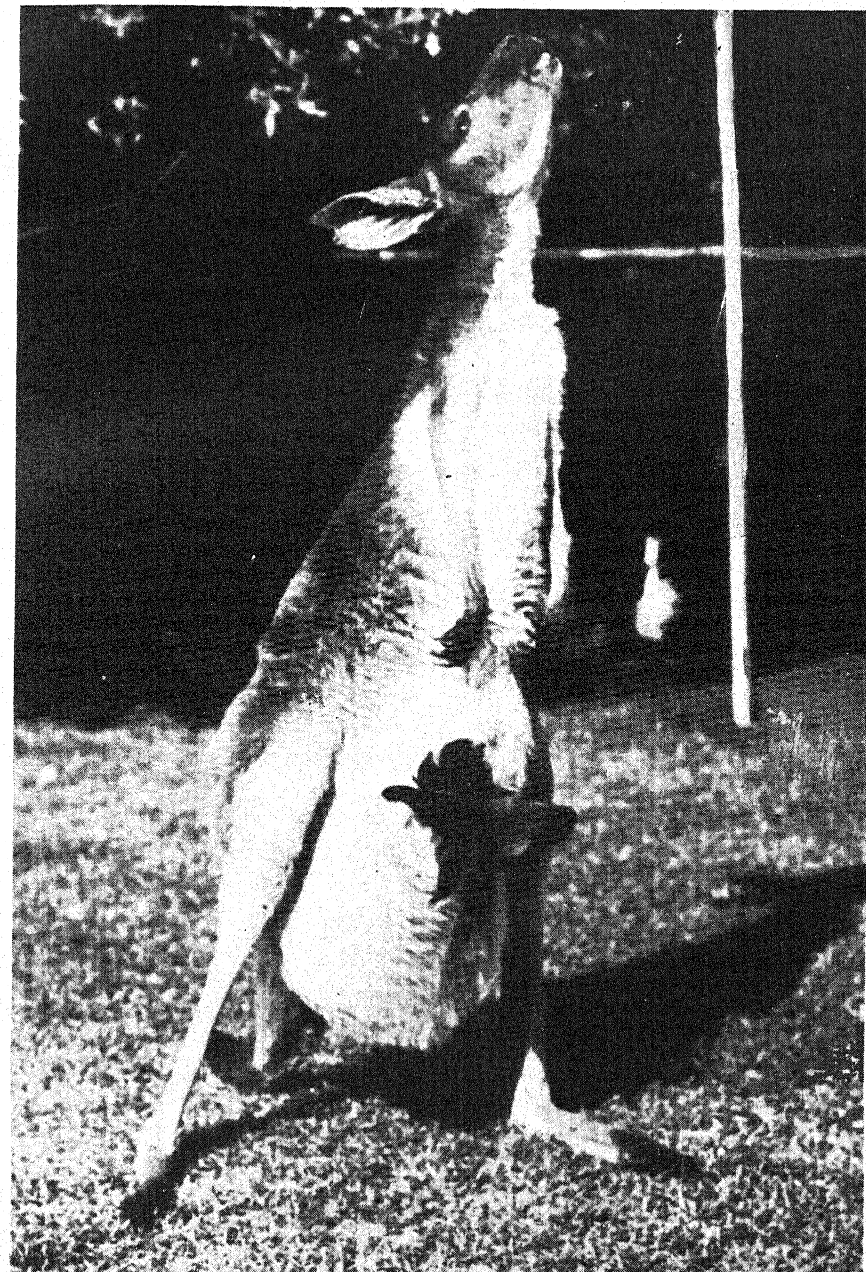
The loose fold of skin and the round tail can readily be seen on both specimens. Photograph by Ernest P. Walker.

BIG BROWN BAT (EPTESICUS FUSCUS).

Wings spread, showing the long arm bones and very long fingers supporting the thin rubberlike flying membrane. The small, short thumb at the wrist is free of the membrane. The tail is partially bent beneath the membrane between the hind legs. Photograph by Ernest P. Walker. The picture was made by placing the bat on a plate of glass over white paper covering a box containing a No. 1 photoflood lamp and illuminating the upper side with a No. 2 photoflood lamp 45° to the left.

FEMALE AND YOUNG GREAT GRAY KANGAROO (MACROPUS GIGANTEUS).

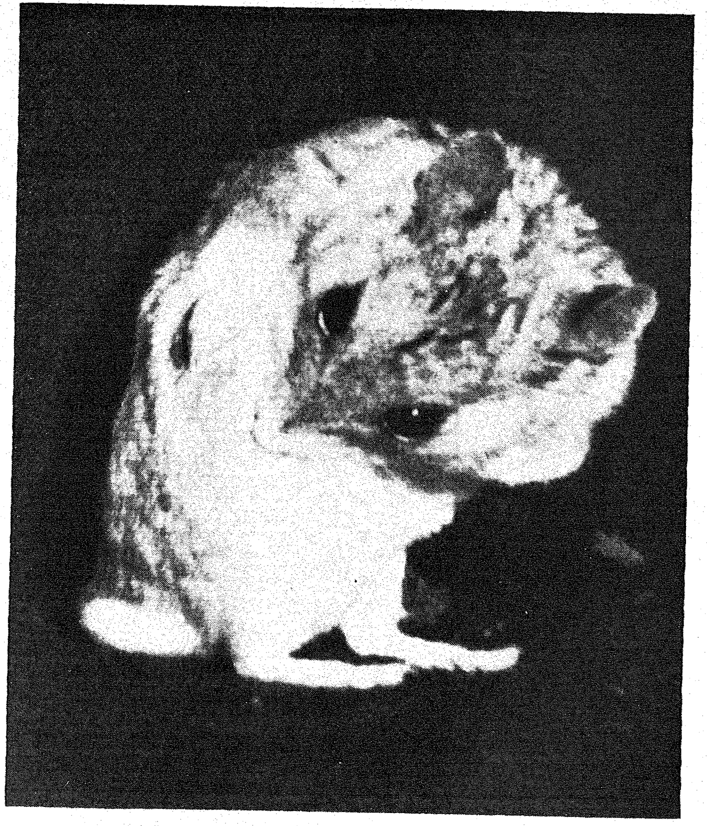
The young is about 5 months old but is still carried in its mother's pouch a portion of the time. In this scene it is using its hands to open the pouch preparatory to scrambling in.
Photograph by Mary Eleanor Browning.



YOUNG GREAT GRAY KANGAROO ABOUT 5 MONTHS OLD IN MOTHER'S POUCH.
The same animal taken on the same day is shown in Plate 10. Photograph by Mary Eleanor Browning.

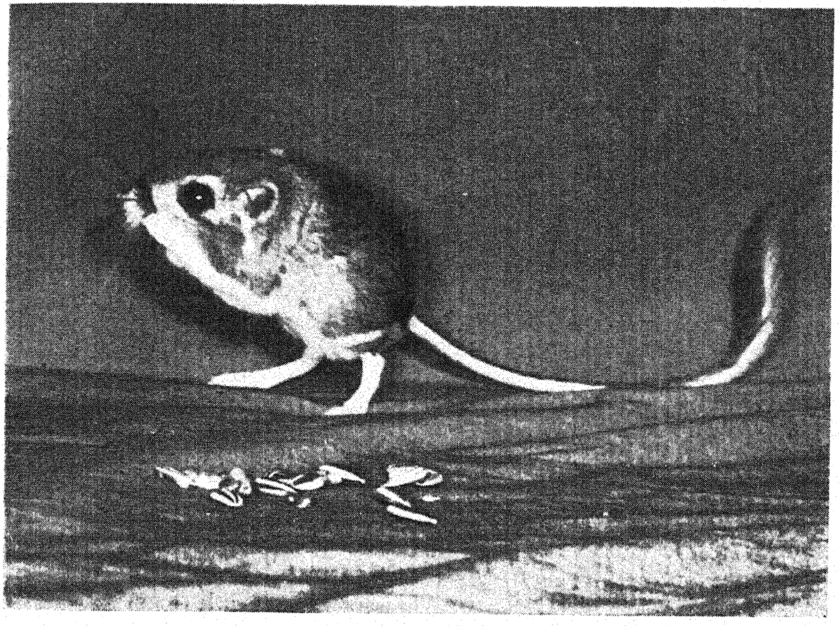
1. "ONY" HOLDING A VERY SMALL CIGAR AND TAKING A BITE OF TOBACCO TO BE CHEWED AND PLACED IN HIS FUR.

Photograph by Ernest P. Walker.



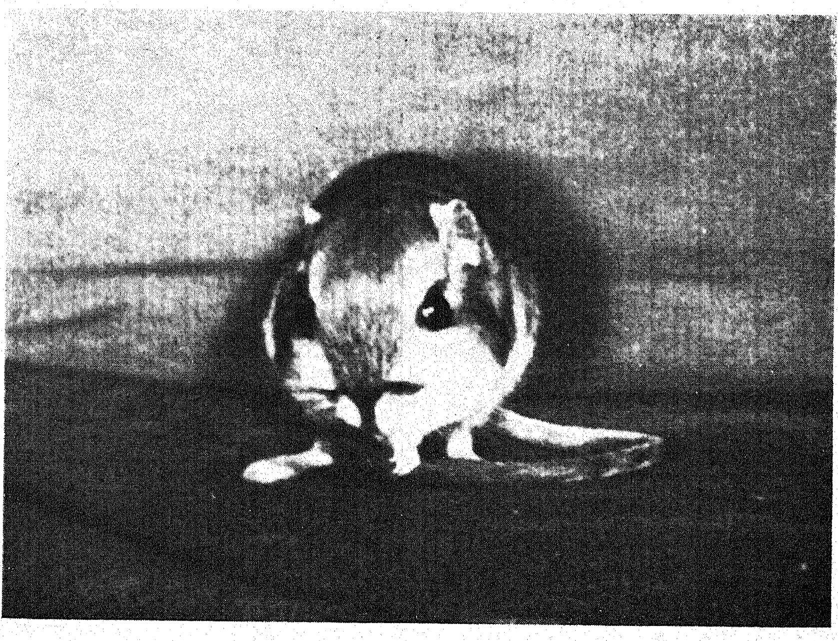
2. "ONY" PLACING CHEWED TOBACCO IN HIS FUR.

Crumbs of the tobacco are in front of him. Photograph by Ernest P. Walker.



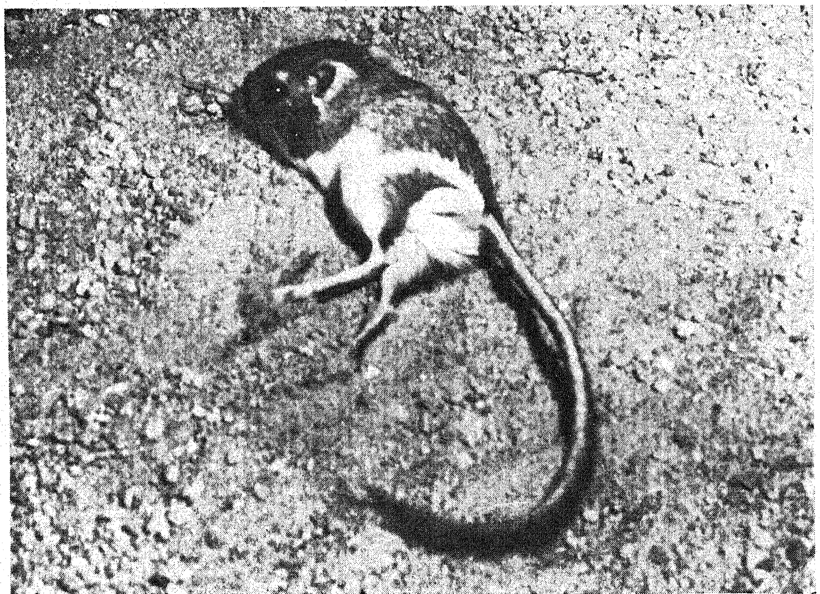
1. "DIPPY," A KANGAROO RAT (DIPODOMYS MERRIAMI), ON HIND FEET, BALANCED BY TAIL.

Photograph by Ernest P. Walker.



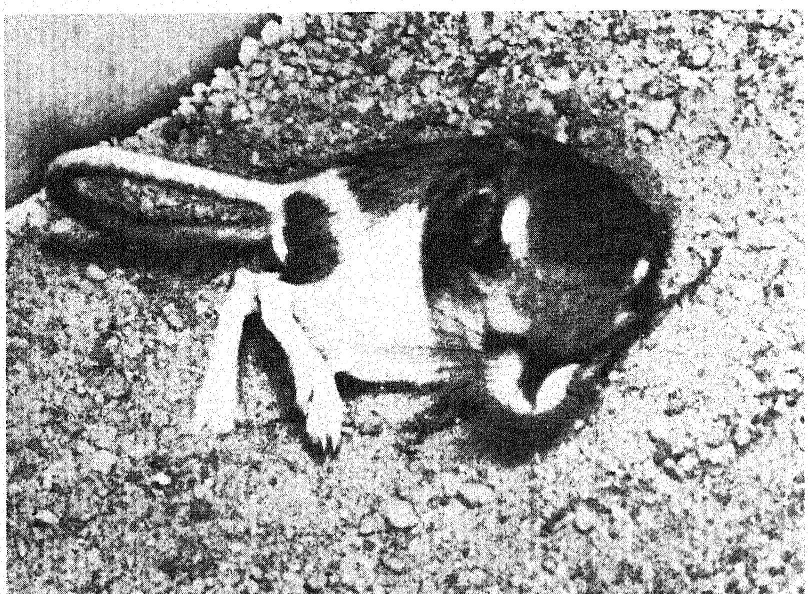
2. "DIPPY" GROOMING THE TIP OF HER TAIL.

Photograph by Ernest P. Walker.



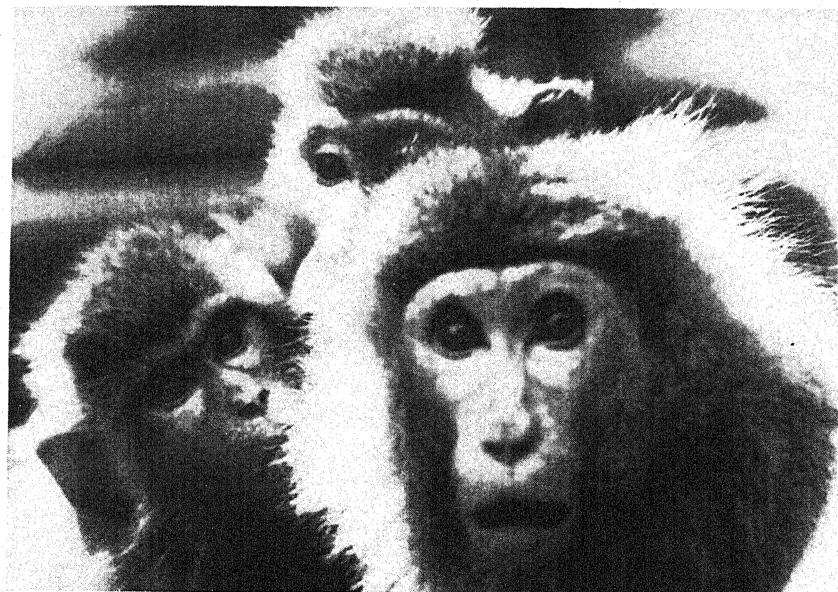
1. A SAND BATH.

"Dippy" cleaning her fur in very fine sand. Photograph by Ernest P. Walker.



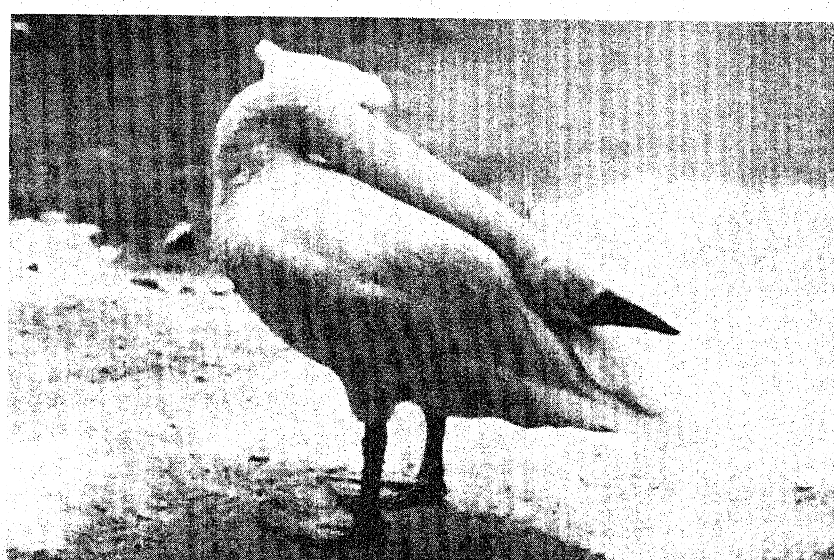
2. "DIPPY" CLEANING HER FUR IN DRY SAND.

Photograph by Ernest P. Walker.



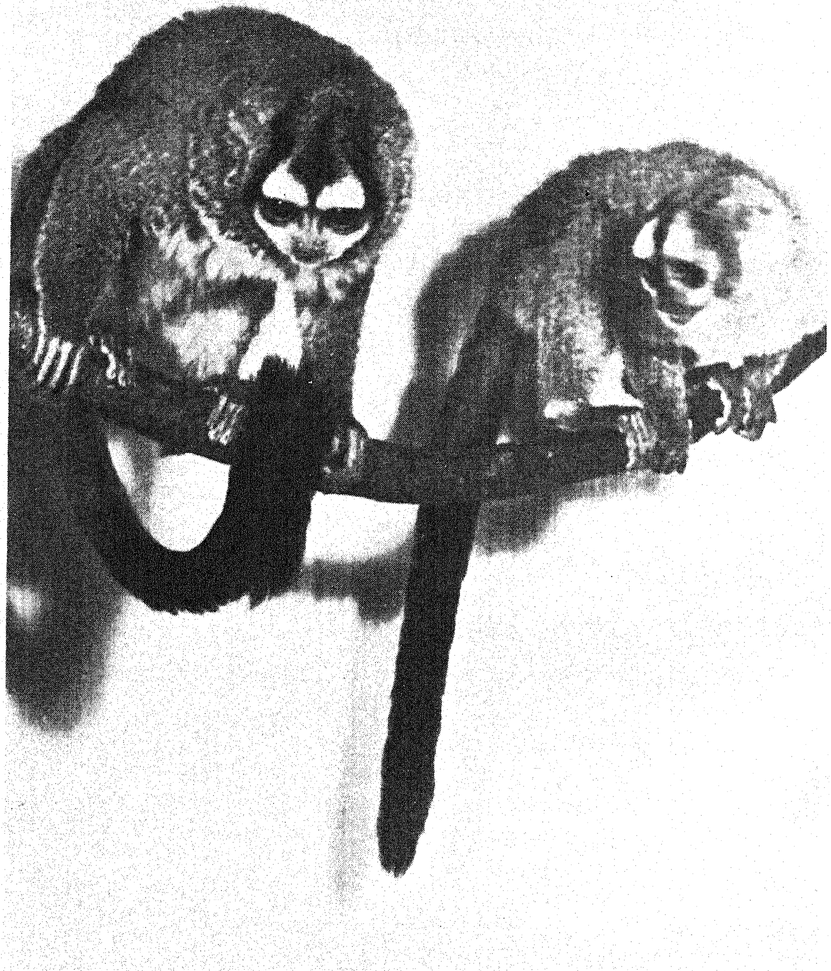
1. JAPANESE MACAQUES (MACACA FUSCATA).

The one in the background has had its hair plucked in a tonsure effect. The other two have normal heads of hair. The face is naturally naked. Photograph from National Zoological Park files.



2. WHISTLING SWAN (CYGNUS COLUMBIANUS) IN AN UNUSUAL POSITION OF PREENING ITS FEATHERS.

Photograph by Ernest P. Walker.

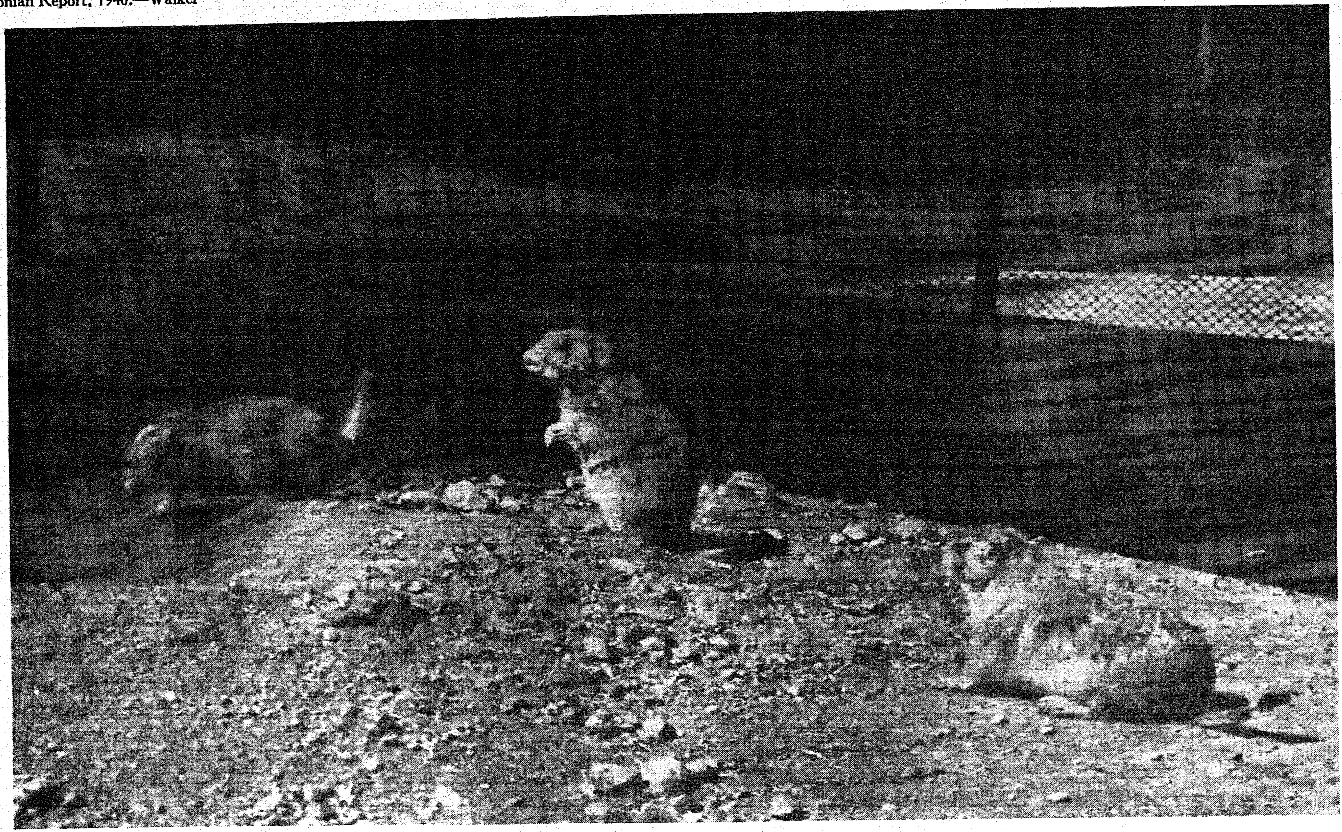


DOUROUCOULIS OR NIGHT MONKEYS (AOTUS TRIVIRGATUS).

The one on the left has just landed on the limb from a leap, and its tail has curled under the limb and up in front to check its momentum. Photograph by Ernest P. Walker.

YOUNG GIBBON (HYLOBATES).

The use of the hands as hooks and of the great toe opposable to the other toes to produce a grasping tool is well shown in this picture. Photograph by Mary Eleanor Browning.



PRAIRIE DOGS IN ENCLOSURES, NATIONAL ZOOLOGICAL PARK.

Photograph by Ernest P. Walker.

THE NATIONAL WILDLIFE REFUGE PROGRAM OF THE FISH AND WILDLIFE SERVICE [1]

By Ira N. Gabrielson

Director, Fish and Wildlife Service
United States Department of the Interior

[With 3 plates]

Every ornithologist is by now familiar with the flyway concept that has resulted from the return records of birds banded over a long period of years. Briefly, this visualizes the birds of certain regions as moving in four wide zones of migration over the country. Some of these flyways overlap somewhat, particularly in the breeding grounds. The birds in the Atlantic flyway, for example, after they reach Chesapeake Bay and from there on south, follow almost entirely a narrow strip of coastal marsh, the great bulk of them moving down the coast or across the Great Lakes and down the Susquehanna and Delaware Rivers. The same is true of the Mississippi Valley, where, although the migration of birds covers a wide band, south of Minnesota it is restricted rapidly to the valleys of the Missouri and Mississippi Rivers, this being largely due to the lack of water in other parts of the flyway. The Central, or mountain, flyway is followed by a smaller group of birds that visit intermittent lakes and sloughs through the Great Plains. The Pacific flight follows the system of great lakes and marshes through eastern Oregon, Washington, and Nevada, but narrows down as it reaches California.

One of the tragic facts in the history of migratory waterfowl has been the shrinkage of their breeding ranges. The region extending north into central Canada from central United States represents the choicest and in some ways the most productive of all the breeding areas. There is a serious decrease in the area available for optimum populations. Another significant fact that must be considered in studying the migratory waterfowl and the development of the national wildlife refuge system is that there is a tremendous concen-

[1] Reprinted by permission, somewhat revised, from an article entitled "The Refuge Program of the Biological Survey," published in Bird-Lore, vol. 41, pp. 325–332, 1939. [The Bureau of Biological Survey and the Bureau of Fisheries were consolidated on June 30, 1939, to form the Fish and Wildlife Service, U. S. Department of the Interior.]

tration of the continent's waterfowl population within a very restricted territory during the winter months. This circumstance makes it imperative that southern marshes be preserved or restored on a vast scale for their use in winter. Basic to the selection of sites for national waterfowl refuges are the two facts (1) that birds move north and south in definite lines and (2) that breeding, wintering, and feeding grounds must be preserved in the areas where the birds need them. If we add the concept that the national refuge system should eventually include a place for every major species of North American wildlife under natural conditions, we have the basic biologic principle on which this refuge program has been developed, particularly in the past 10 years.

The Federal refuge program administered by the Fish and Wildlife Service was initiated when President Theodore Roosevelt set aside Pelican Island on March 14, 1903. The refuge system grew slowly from that time on, but funds for the proper administration and maintenance of areas did not follow the growth of the system. It was not until the passage of the Upper Mississippi River Wildlife and Fish Refuge Act, on June 7, 1924, that the first of our large waterfowl refuges was established. This was followed by the Bear River Marsh Refuge Act of April 23, 1928. In both cases funds were provided. Before this, however, Malheur Lake and Lower Klamath Lake had been added from Government land and also a few other areas. The National Bison Range had been established by an act of Congress on May 23, 1938. This range provided the first national home made particularly for the fast-vanishing buffalo.

With the passage of the Migratory Bird Conservation Act, on February 18, 1929, which authorized appropriations of some $10,000,000 to purchase and develop waterfowl refuges, the national program really got under way. The authorizations provided in this act were never reached, but some money was appropriated and a number of refuges were purchased and developed under this program. On July 1, 1933, approximately 6,000,000 acres of land were embraced in the refuge system. Beginning on that date emergency money of various kinds became available to extend and accelerate the refuge program, so that at the end of June 1940 there were 13,635,365 acres in the Federal refuge system. Additional impetus was given to the movement by the passage, on March 16, 1934, of the Migratory Bird Hunting Stamp Act, which has to date produced more than $4,500,000 for the development of this program. This "duck stamp" money is available for the purchase, development, and maintenance of a Federal refuge system for the migratory waterfowl, and the money must be so used.

Embraced in the Federal system are several types of refuges. The first that might be mentioned are those set aside usually to protect

colonies of interesting nongame birds. Many of these consist of islands in rivers or lakes where breeding colony-nesting forms are protected. For example, those on the Oregon coast protect colonies of murres, puffins, cormorants, and similar birds. Anaho Island in Pyramid Lake offers sanctuary for a great nesting colony of pelicans. Those on the Florida coast protect colonies of brown pelicans, herons, and egrets of various kinds. A number of these have been added in recent years, and the tendency is for more of this type to be established. One of the difficulties in developing such a program is that while some birds remain in the refuges, others, including the brown pelicans, herons, and egrets of Florida, do not. They will nest on some island for a number of years and then abandon it for an adjoining one. It is the policy of the Service to retain title to all these islands, however, in the event that the birds should move back at some future time, and to add new ones when utilized.

As money has become available, an increasingly efficient work service has added to the protection accorded these refuges for nongame birds and increased their value for the purpose for which established. The latest refuge of this character is the Great White Heron Refuge, which has been added directly to the Key West Refuge. It occupies several hundred small islands that extend for a distance of approximately 60 or 70 miles along the Florida Keys. This refuge is giving protection to the great white heron and the white-crowned pigeon, as well as to numerous other birds that frequent the area.

There is also the national big-game refuge system, which began with the establishment of the National Bison Range in Montana. This has expanded greatly in recent years with the growth of the plan. There should be an area provided for each major species of animal within its natural range. With this in mind, the Little Pend Oreille in northern Washington was set aside and developed particularly to preserve the large white-tailed deer found in that territory. Hart Mountain and Charles Sheldon, between them, preserve the antelope and the sage hen. The Desert Game Range in Nevada and the Kofa and Cabeza Prieta in Arizona protect the fast-vanishing bighorn sheep. Others on this list are ecological types and areas that should eventually be included in this system, where indigenous species of upland game may be preserved for all future time. These refuges vary in size from less than 1,000 acres (Sullys Hill) to something over 2,000,000 (Desert Game Range) and are adequate for the purpose for which developed. At the present time all are under tentative management and patrol, with the purpose of building up the herds of animals that are on them.

The concentration of refuges for migratory waterfowl along the Atlantic coast and along the Mississippi Valley indicates the significant grouping of these areas. This is noticeable also in the concentration of such refuges in northern California, across Nevada, Utah, Wyoming, and Nebraska, and into Minnesota, Iowa, and Wisconsin. These represent restoration or improvement of breeding-ground areas and are an important contribution to the restoration of suitable environmental conditions for the migratory game birds in these territories. We have by no means completed this part of the program. In addition to purchased areas we have surveyed something over 8,000,000 acres of marsh or potential marshland, which may include areas that can be developed into new marshes or old marshland that may be purchased and restored at a reasonable figure. These proposed areas, if added to the existing ones, would adequately provide feeding and wintering grounds for the present stocks of migratory waterfowl. They would also add to the breeding-ground area of such major refuges as it is now possible to purchase and develop at a reasonable cost. It is unquestionably true that more of these areas will become available in the future as economic conditions change.

The ultimate objective in developing this system of refuges is to restore every acre of marsh in the breeding range of waterfowl that can be restored. We have more than reached the halfway point, and a great increase has taken place in the past 7 years. It will require in the neighborhood of $10,000,000 of land-purchase money to add to this refuge system the major units that are still lacking and that are available at a reasonable figure.

An interesting side line of the waterfowl refuge system, which has for its purpose the development of existing small breeding areas, was inaugurated in North Dakota a number of years ago and has now spread to Montana, Wyoming, and some of the other neighboring States. This is the so-called easement refuge program, wherein the Fish and Wildlife Service provides the engineering supervision, W. P. A. labor develops the structures and does the work, and the landowners give perpetual easement to the Federal Government to flood the land and to maintain these units as migratory waterfowl breeding refuges. There are now 84 of these projects, and the total acreage restored by them runs to about 147,000. These refuges vary in size from 160 acres up, but each has restored an old marsh or developed a new one to replace those that have been destroyed by drainage and drought combined. Thousands of similar areas can be restored as money to do it becomes available. We have on file applications from landowners and others for hundreds of additional projects of this nature. These will require only such restoration of

original environmental conditions as is possible. This refuge program has been fitted into others, being made to serve the purposes of flood control, soil-erosion prevention, and the development of local water supplies for people in the communities and other needs, provided that they do not interfere with the primary purpose for which the refuges are being created.

The Souris River projects afford a good example of these multiple benefits. There are three projects, one on the Des Lacs, a tributary of the Souris, and one on each of the Upper and Lower reaches of the Souris River as it enters this country from Canada and leaves to return to that country. Our engineering operations have provided not only one of the major nesting and breeding units in the whole refuge system but have also furnished flood protection for the remainder of the valley, storing the run-off water for summer use, and restoring water levels so that wells are not going dry. They also provide a limited number of recreational facilities in places where these will not interfere with the birds.

Although built for the primary purpose of restoring environment for migratory waterfowl, these refuges are serving the same purpose for countless other birds. While we talk in terms of migratory waterfowl, because it is largely migratory waterfowl money that is being used, we do not forget that we cannot restore marshes and lakes and make other improvements without extending benefits to all forms of wildlife frequenting such areas. There has been a tremendous increase in the number of individuals and in the variety of species of breeding birds within the Souris River area, and there have been 114 species of breeding birds reported in the Lower Souris project alone since it was established and developed. Among other species that I have seen there myself are colonies of Sprague's pipit and Baird's sparrow (two varieties not too easily found by the average ornithologist). Numerous other species, including grebes, terns, gulls, and herons are coming back in increasing numbers each year to utilize the facilities made available to them. Both prairie chickens and sharp-tailed grouse are found on some 25 of these waterfowl refuges in numbers to make a fine breeding population and probably to insure the perpetuation of the species.

The Lower Souris refuge also has a population of some 500 to 600 white-tailed deer—more deer than I had thought were left in North Dakota. This population has built up rapidly following the posting and patrolling of the refuge and its development for wildlife. The accomplishments of the past few years have been the most hopeful ones in the history of the efforts to conserve American wildlife species and to insure their perpetuation. Such organizations as the C. C. C. camps, the W. P. A., and other relief agencies have contributed

mightily to the development of these areas. We should be far behind our present program had it not been for the aid rendered by the personnel made available from these agencies.

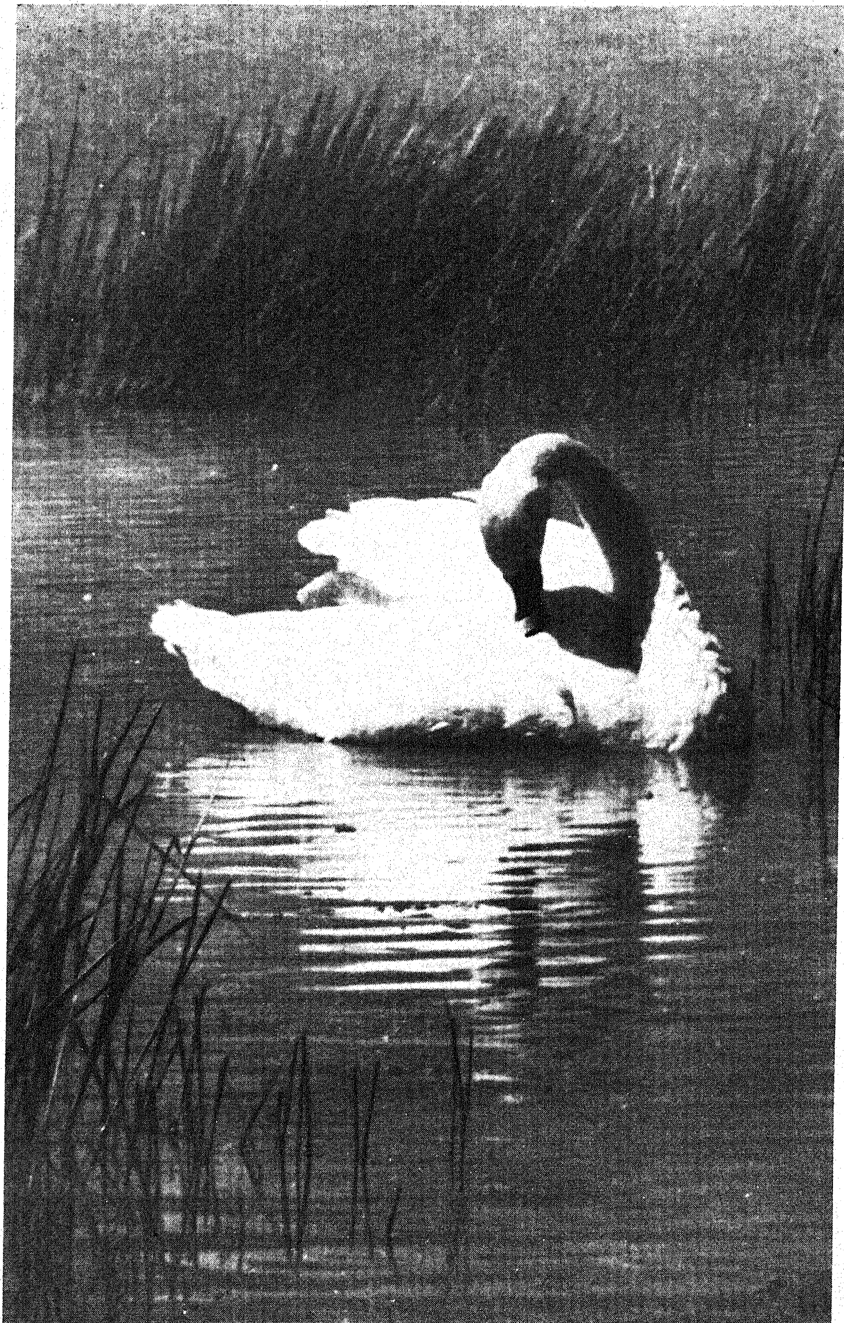
We feel that it is necessary to have at least 3,500,000 additional acres of marsh in strategic points before we can be absolutely assured of the safety of the migratory waterfowl population. This acreage, if and when it is restored, will also mean much to all the nongame species that utilize marsh environments.

There is one other thing that should be mentioned in this very brief review of the present status of the refuge program; that is that in 1939 there was dedicated near Washington the Patuxent Wildlife Research Refuge, with adequate buildings provided, or in course of construction, to make it a great wildlife-research center. There, eventually, will be housed the entire wildlife-research laboratories of the Fish and Wildlife Service, which previously were in Washington, new laboratories that have been developed, and personnel for new studies that are being undertaken on this area. The refuge consists of 3,000 acres of land, woods, and water, within an hour's ride of Washington. It is now available to the scientific staff for any kind of experimental or observational use they may care to make of it. It is expected and planned that long-time studies about the relationships of species of wildlife with each other, with agricultural crops, and with changing environments will be set up there in places and under conditions that will permit them to go on for many years without being disturbed. It is our hope to institute on this refuge such long-time studies as it is impossible to make on land where administrative control cannot be practiced by the research agency or where changing administrative policies may destroy a research program just at the time it begins to be of practical application. It is hoped to build up a complete history of the work and observations carried on in this area, so that as the years go by it will become increasingly valuable to the ornithologists, mammalogists, and other scientific men of this country as a source of information. It will also provide us with much-needed data for a wiser and saner administration of the land now in the refuge system.

It is the present policy of the Fish and Wildlife Service to be guided in administrative policies by research findings. I assume that this is an ideal condition that will never be completely attained. Research men are impatient when their findings are not soon put into practice; on the other hand, other men are impatient if the research men do not find the solutions promptly. Even after a solution is found and tested, it takes time to change the program of a refuge system as large and as scattered as that of the Fish and Wildlife Service has now come to be. Previously we were not in a position to invite people to make free use of the refuges. During the period of

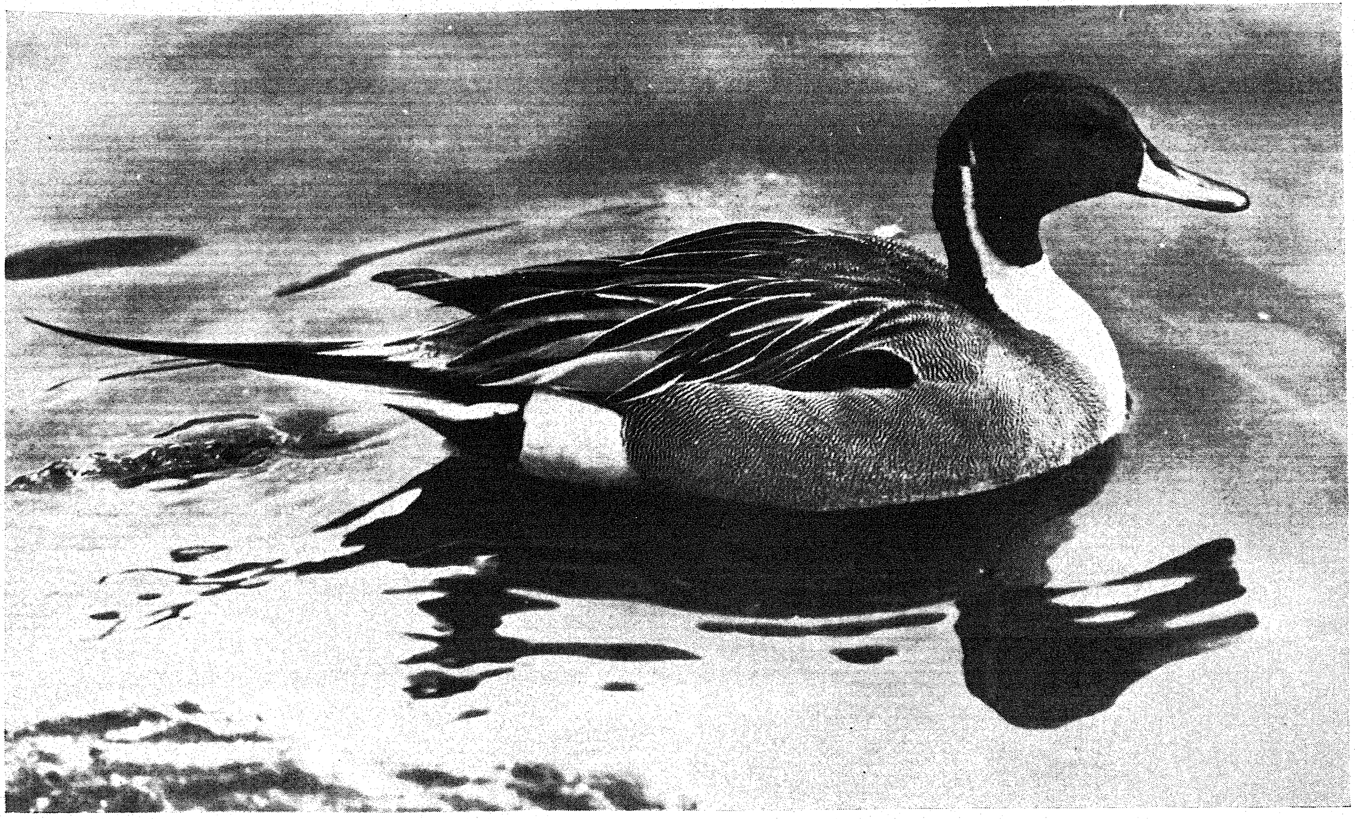
construction we did not feel like burdening the limited personnel with the duties of looking after people on the refuges and providing for their wants, although I do not believe that the Service has refused a single request for permission to do scientific work on any refuge, even though it might inconvenience the personnel during the developmental period. As the refuges pass beyond this stage—and by that I mean the period of construction of necessary dams and dikes in order to restore water, the building of fences and the other things necessary to keep out the stock, the completion of administration buildings, and the provision of similar equipment necessary to develop a real refuge program—we look forward to being able to give more attention to other phases of the work. All are invited to feel free to use these refuges in making studies of bird and animal life. The Service will be more than pleased to offer its cooperation and all available facilities in these areas. These facilities will be found to vary according to the location and the available personnel. Some refuges have modern and convenient laboratories situated on the ground, while others have the most primitive, wild conditions that could be found in areas not yet and probably never to be developed.

Our Service is proud, and we believe justly so, of the accomplishments along these lines during the past few years. We look forward with confidence to the time when we shall be able to say (and we hope that it will not be far in the future) that the refuge areas in this country are adequate to insure, so far as human provision is possible, that not one remaining species of American wildlife will vanish from the face of the earth.



TRUMPETER SWAN.

Once faced with extinction, the trumpeter swan population in this country has now reached the optimistic figure of 199 individuals, all of them concentrated on the Red Rocks Migratory Waterfowl Refuge in Montana and in Yellowstone National Park, Wyo. Photograph by U. S. Biological Survey.



PINTAIL.

Pausing in its migration, the graceful pintail finds protection and an abundance of food on the Federal refuges scattered along its flyways. Photograph by Allan D. Cruickshank.

CANADA GEESE AND YOUNG.

The waterfowl refuge produces results. While the family group is moving about on the water, the gander usually takes the lead, the goslings follow, and the goose acts as rear guard.
Photograph by Allan D. Cruickshank.

A LIVING FOSSIL[1]

(Latimeria chalumnae J. L. B. Smith)

By J. L. B. Smith
Rhodes University College, Grahamstown, South Africa

[With 3 plates]

Scientific discovery rarely follows a smooth and orderly course. Like most natural processes it proceeds spasmodically, and important results frequently come only after long-drawn-out, exhausting, and apparently fruitless endeavor, sometimes even almost by what appears to be a lucky chance. Scientific discoveries may roughly be divided into two main classes: Those which affect the material welfare of mankind (e. g., the existence and action of bacteria) and those which represent merely an addition to knowledge. There has recently been discovered near East London, South Africa, a very remarkable fish which represents an event of the latter sort. The interest it has aroused is on account of the great scientific importance which attaches to it. It is a living link with a past so remote as to be almost beyond the grasp of the ordinary mind.

In order that the full significance of the discovery may be appreciated, we may recapitulate briefly a few outlines of the theory of evolution. By methods which space does not permit to be explained here, scientists have been able to arrive at an approximate time scale for the comparatively recent part of the history of the earth. According to that scale, life, animal life of sorts, was present in at least some waters of the earth 400 million years ago. We do not know exactly when or where or how that life originated. In the rocks are traces which to experts represent vanished forms. Most of this evidence is in the form of what are known as "fossils." These are the petrified remains of creatures which died in such fashion that their bodies were covered by mud or sand or sludge which to some extent preserved the main structures. At some later date the embedding material was converted by various processes, e. g., pressure, infiltration, etc., into rock. Those records in the rocks are to the paleontologist

[1] Reprinted by permission from The Cape Naturalist, vol. 1, No. 6, July 1939.

something like a book whose leaves can by incredible patience be unfolded. Naturally the oldest records lie in the deepest strata, and those are generally the most distorted and very difficult to read. The record is not complete—there are distressing gaps. In some cases where one class of creature is known to have originated from an ancestral form, no intermediate or "missing link" can be found. The two forms may coexist, and be traced back for a long period in this record in the rocks, showing closer and closer relationship in structure, so as to leave no doubt about the origin of the descendant form. Suddenly in this working back, all signs of the later form cease, and earlier strata will show no traces of it. Thus it sometimes seems as if the new class of creature had suddenly appeared full-fledged and complete. In other cases, however, the developmental or evolutionary record is fortunately complete.

Beyond the disputes of scientists about minor points is the fact that fishes of sorts were the ancestral forms from which all other vertebrate creatures have originated. We have no record of any accepted "link" between these fishes and their most likely invertebrate ancestors. The fishes are suddenly there, some 370 million years ago, in numbers, and in a diversity of weird forms. From the fishes originated the amphibia, and from them the reptiles. These were all cold-blooded creatures, very much at the mercy of sudden climatic changes. The first amphibia appeared about 320 million years ago, and reptiles evolved from them by 90 to 100 million years later. Those sluggish creatures were produced by nature in great diversity of size and shape, but most of the larger forms in specialized groups have become extinct.

The call for greater activity and mobility produced from the reptiles the warm-blooded birds and mammals, the latter class, as typified by man, being now dominant on the earth.

To return to those early fishes, some of which were our ancestors: Many of them, the only ones we know, left traces in the rocks. Usually the skeleton and any teeth, spines, or hard skins are preserved, in rare cases perfectly. The "soft parts" are largely unknown, and the reconstructed outlines of extinct forms are to some extent guesswork, but no more guesswork than the diagnosis of appendicitis by a physician. In each case visualization of the hidden condition is based upon experience and knowledge. How close such visualization may come to actuality may be seen on comparing the outline of a Coelacanthid fish thus reconstructed (fig. 2) with the photograph of the present-day fish. (pl. 1).

The primitive ancestral form of fishes was almost certainly something rather sharklike, without any true bone in its make-up. From those creatures in a relatively brief period of time evolved a multiplicity of types which are generally divided by scientists into four main

groups. These are known as the Placoderms (clumsy "armor-plated fishes"), the Marsipobranchs (jawless sucking-mouthed fishes), the Selachians (fishes with cartilaginous skeletons), and Pisces (fishes with bony skeletons). Many were experimental forms which found competition too severe and so vanished. All of the first group are extinct. They were too clumsy. There are a few miserable remnants of the Marsipobranchs still alive today (hagfish and lampreys). The Selachii are the sharks and rays which have remained vigorous and numerous, and which are one of the great forces in the waters of the earth. In the vast periods of time since their ancestors first spread terror in prehistoric waters, the sharks have changed perhaps less than any other creatures. Many became extinct, but the line was carried on by forms of vigor and activity. Under Pisces are grouped the vast majority of living fishes, and a number who have vanished, some of great significance in the ancestral line.

The immediate importance of this recent discovery lies in the information it affords us about the developmental processes which have led to the typical forms of fishes, and which have been the subject of much research and speculation. This Coelacanthid specimen sheds a great deal of light upon many of those questions, since for some reason parts of this fish are in a condition which may be termed arrested metamorphosis. That is, it bears certain structures which are in process of changing from one thing into another, but the change has not gone to completion. Many of the outer bones of the head in fishes are supposed to have been derived from scales. Also the teeth in the jaws of fishes are believed to be merely scales that have migrated inward and have been changed into tooth-bearing structures. Fins are regarded as having originated from continuous folds of skin developed as stabilizers along the long axis of the body. On these and on many other points the present specimen affords a great deal of important evidence.

The main outline of the evolution of various types belonging to the two chief groups of fishes is shown by the accompanying diagram, which is not to scale. Branches which reach the line 1939 represent groups and forms which have survived to the present day. The others represent extinct forms. The cross-hatched line shows the addition to this scheme necessitated by the recent discovery.

One of the great main branches of the evolutionary tree was the group of the Crossopterygii (or fringe-finned). They were mostly large active predaceous fishes that probably dominated the extensive areas in which they occurred. Like most fishes they originated in fresh water and later migrated to the sea. A large number of forms developed, and were characterized by this peculiar "fringe-finned"

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state, and by the heavy bony armature of the head. Many were not very different from the primitive sharklike ancestor, since their inner skeleton consisted at least partly of cartilage or gristle. They were covered by heavy scales, the outer surface of which was ornamented by an enamellike substance known as ganoin. Many of them possessed most peculiar tails, known as gephyrocercal, which are really two tails in one, the extreme tip being a remnant of the original true tail which degenerated. Their pectoral and pelvic fins had developed so as to be very like limbs. It had been supposed that the

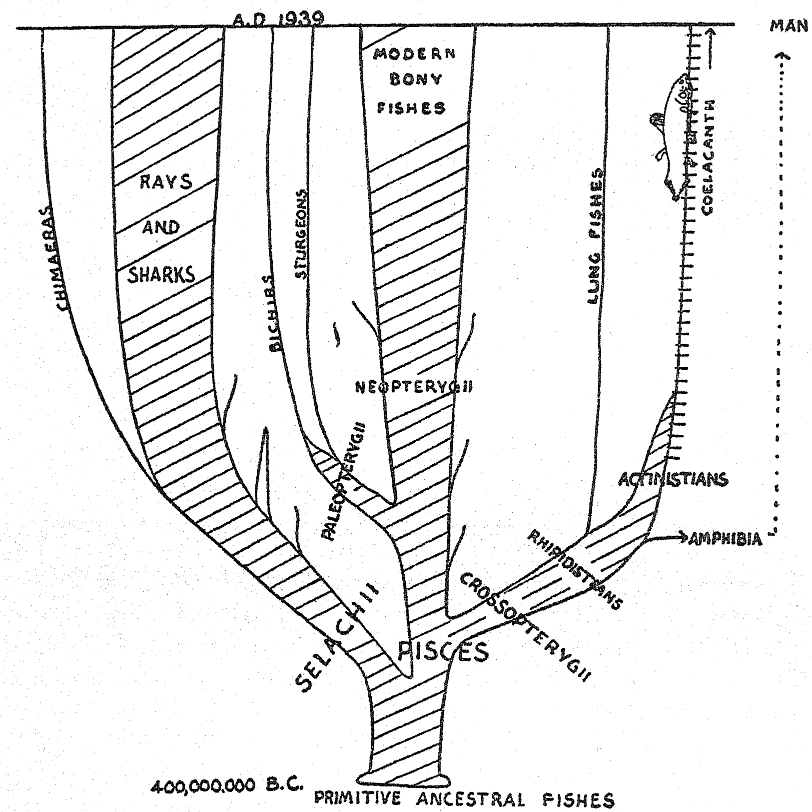


FIGURE 1.—Diagram illustrating the main lines of the evolution of fishes belonging to the groups Selachians and Pisces.

sole living representatives of this ancient line were the few rather scarce species of "lungfishes" living in fresh water in America, Australia, and Africa. They are degenerate forms which are but feeble shadows of their active and predaceous ancestors.

After having lived and flourished for some 250 million years all those other numerous and vigorous Crossopterygian fishes had been supposed to have become extinct by 50 million years ago. The record in the rocks showed how, after having occurred in great num-

bers over a wide area, they diminished, until finally all traces ceased before the end of the Mesozoic era—50 million years ago. Those important fishes had all vanished. Important because they were a link between the early intriguing creatures about whose structure we know so little, and the later vertebrates which have given rise finally to man.

The Crossopterygian stock developed principally through a group known as the Rhipidistians. These flourished from 300 million years ago for about 100 million years. Some of those fishes were the ancestral forms which gave rise, almost simultaneously, to three branches of the evolutionary tree: (*a*) The lungfishes, a thin feeble line that has survived by living an almost isolated life under conditions that scarcely any other creatures can stand; (*b*) Actinistian fishes, the Coelacanthidae, a vigorous branch that flourished for a long period and then just petered out long ago (or was thought to have done so); and (*c*) the amphibia, the origin of all land vertebrates. The two latter groups must have budded off from the parent stock very close together. It is not even unlikely that some of the early Coelacanthids made expeditions ashore along with those unknown amphibian ancestors. If that is so, then for some reason they returned to the water, and extinction, while the amphibian stock multiplied and throve.

Because of their close connection with the origin of land vertebrates, Crossopterygian fishes have been the subject of most intensive researches. In only a few cases have scientists been able to find anything like complete remains. Mostly there are fragments. In almost all cases the bones of the front part of the snout are missing. There have been found very few clues as to structure other than of the hard parts. All very tantalizing, especially as that "missing link" between fishes and amphibians is still missing.

Now, suddenly, there has appeared this great 5-foot fish, bearing the full panoply of his early Mesozoic forbears, but larger than any of them. He is neither puny nor degenerate like the lungfishes, but a great robust animal prepared and fitted to face all the risks in the sea (except a trawl net!). It is as if a fish of 150 million years ago had suddenly come to life. In that incomprehensibly long stretch of time this species has remained virtually unchanged, evidently completely satisfied with itself. In every way this is a true Coelacanthid from that remote past. For at least 150 million years this representative of that ancient but vigorous line has lived in such obscurity as never to have left any known traces of its existence.

The discovery of this Coelacanth is a confirmatory link in the chain of evidence upon which the theory of evolution is based. It stands as a high tribute to the reconstructional ability of scientists

who have had to work chiefly with distorted and fragmentary remains. Although the scientists engaged in such work have been reasonably confident that their reconstructions were fairly close to the truth, there naturally remained a certain element of doubt. It appeared that there could never be any possibility of comparing their efforts with actual specimens, and many people regarded those reconstructions as mere phantasies. This Coelacanth shows that the scientists, in this case at least, have been remarkably accurate in their reconstructions. Even the layman can see how close is the reconstructed form of a Mesozoic Coelacanth to that of the recent fish of East London, South Africa.

Naturally enough this fish will fill in many of the gaps in our knowledge of those earlier forms. What is as important is that the discovery makes it at least possible that there may be other primitive creatures, believed long since extinct, lurking unsuspected in the depths of the ocean. It is more than likely that there is a real "sea-serpent." So many reliable persons have testified independently to having seen that creature (or those creatures) that it cannot all be fabrication. We know almost nothing about what may be present in the depths of the ocean.

I have been asked where this fish is likely to have lived. My opinion—it can be only a guess—is that the species lives among rocky ledges where trawlers cannot operate, and at depths greater than that at which line fishing is practicable. But a number of factors incline me to believe that it does not live at very great depths. Probably 100 to 200 fathoms, along the outer ledges where rocky slopes fade down into the abyss, these Coelacanths lead a "coney-like" existence. Our specimen is probably a stray. There is reliable evidence that others have been seen on our coasts. We hope that the advent of other specimens will be not long delayed. We may even expect other species.

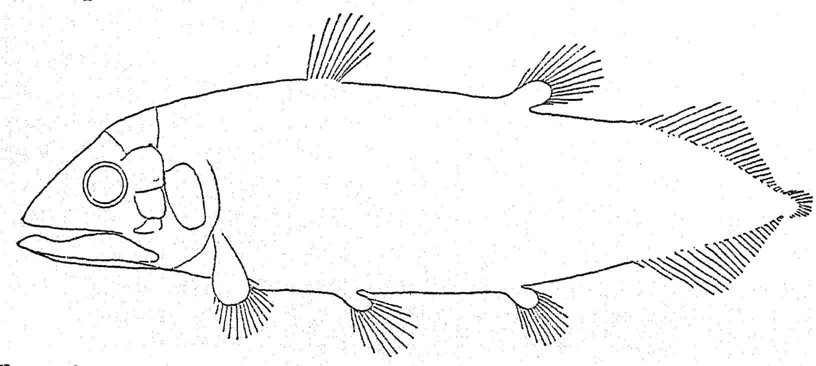
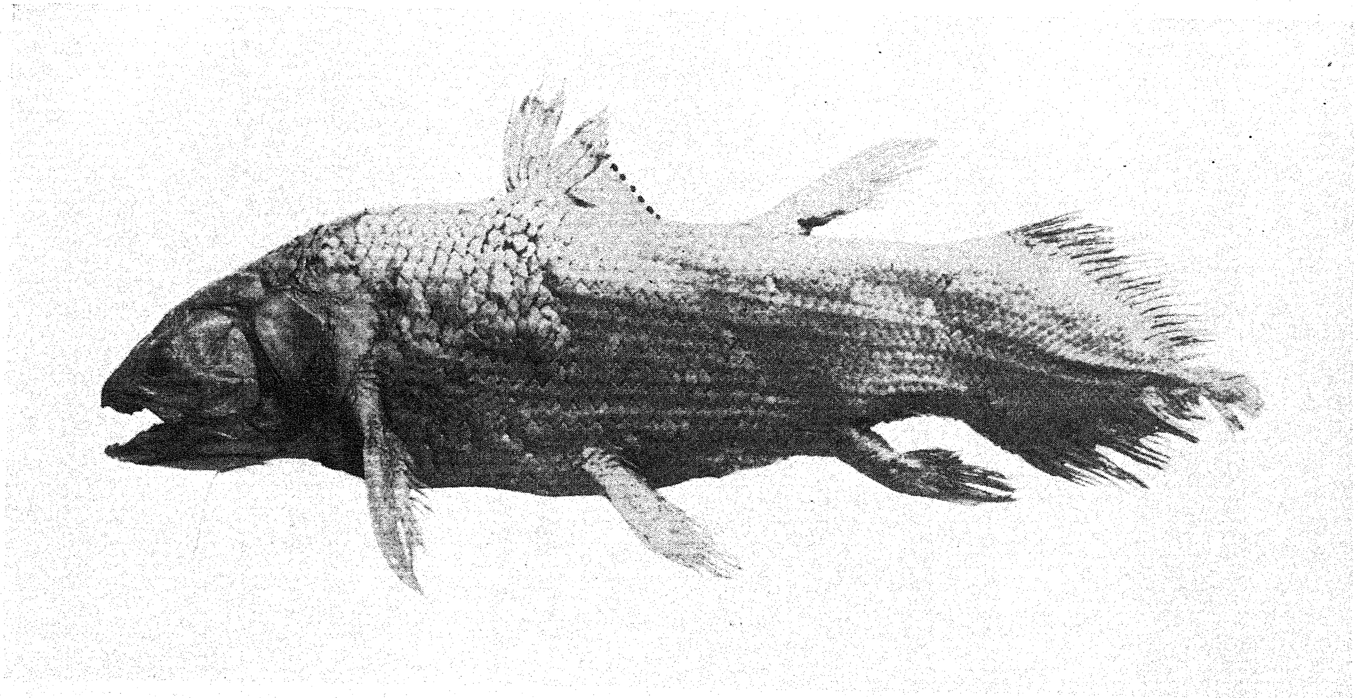


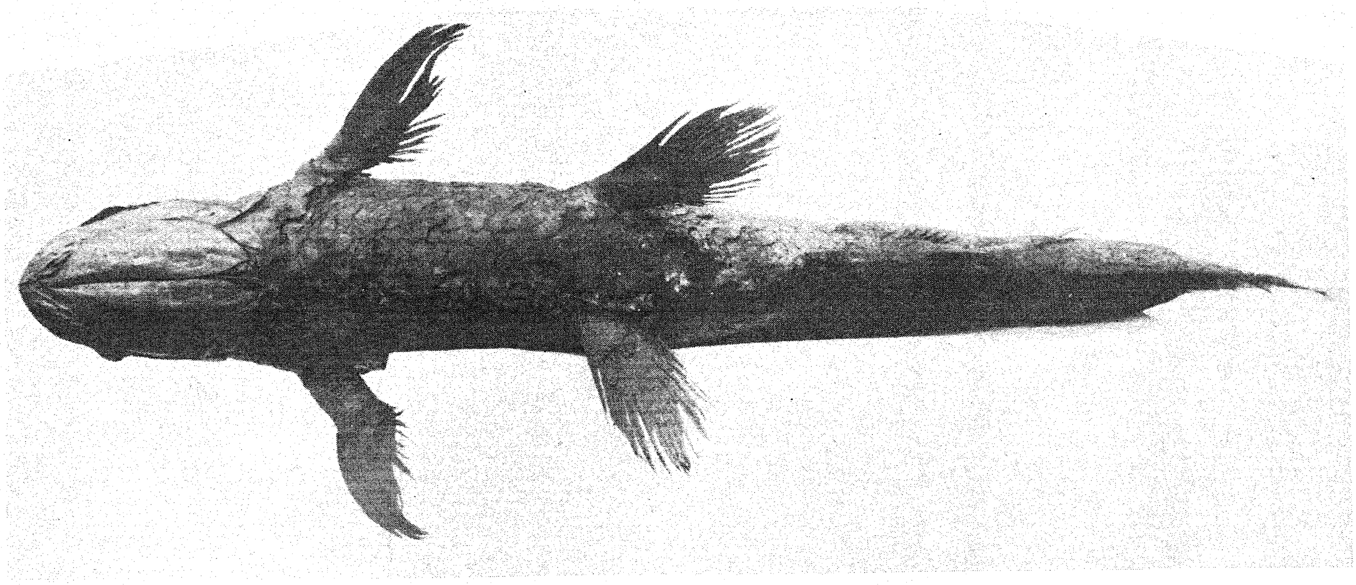
FIGURE 2.—The outline of a Coelacanthid fish, which lived about 150 million years ago, as reconstructed from fossil remains.

For those who are interested, the full classification of this fish is as follows: Class: Pisces. Subclass: Crossopterygii. Order: Actinistia. Family: Coelacanthidae. Genus: *Latimeria.* Species: *chalumnae.* The genus and the species are new to science. The genus has been named after Miss Courtenay-Latimer, Curator of the East London Museum, whose energy and enthusiasm have obtained many valuable specimens. *Chalumnae*, the specific name, refers to the locality in which the species was collected, off the mouth of the Chalumna River, some miles west of East London.



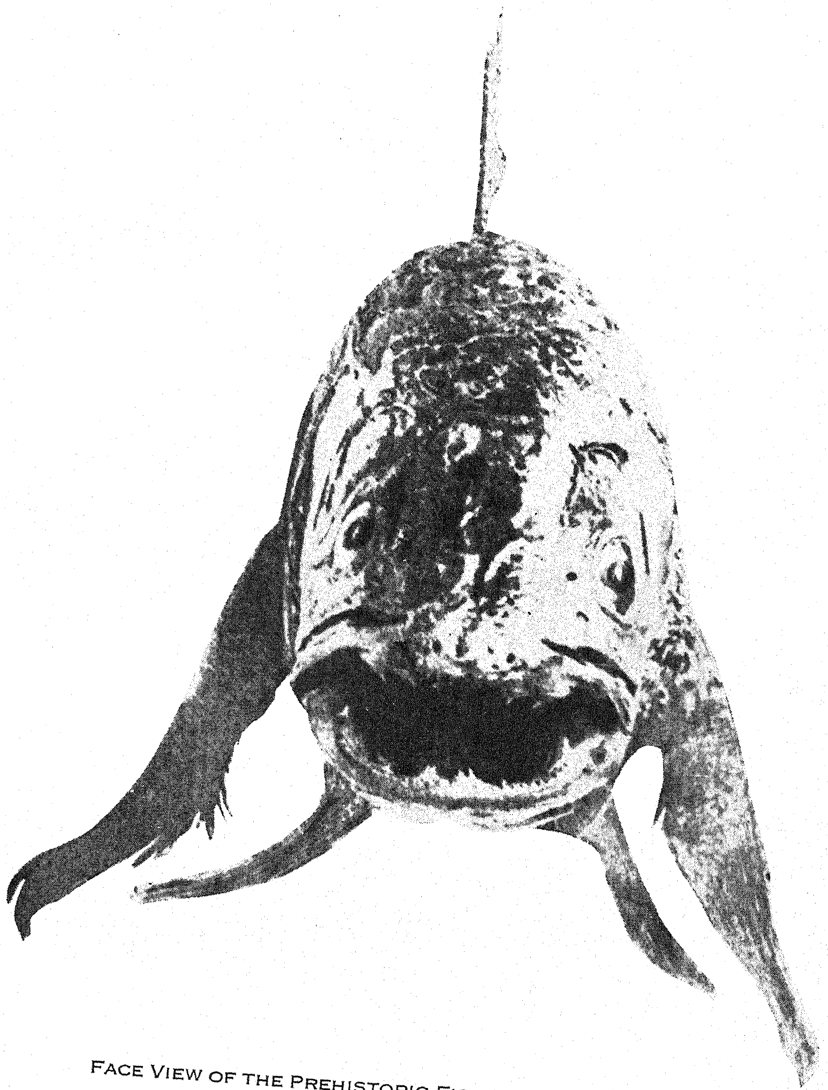
1. LATIMERIA CHALUMNAE J. L. B. SMITH.

The Coelacanthid fish from East London whose discovery is regarded as the most important event in natural history in the twentieth century. This fish, of a type believed to have become extinct in Mesozoic times, was taken by trawlnet at depth of 40 fathoms, some miles west of East London. It was 5 feet long, a bright metallic blue, and weighed 127 pounds. Note the solid fringed fins, very like limbs. The little tufted stump at the hinder end represents the degenerate true tail. The shaded portion replaces a missing part of the dorsal fin.



LATIMERIA CHALUMNAE J. L. B. SMITH.

Seen from below. Note reptilian appearance and the two hard plates under the lower jaw. These plates are a regular feature of extinct fishes but absent from modern ones. Much reduced; the fish is 5 feet long.



FACE VIEW OF THE PREHISTORIC FISH FROM EAST LONDON.

INSECTS AND THE SPREAD OF PLANT DISEASES[1]

By Walter Carter
Pineapple Experiment Station, Honolulu, T. H.

[With 6 plates]

Insects are recognized as important factors in agriculture on account of their direct attack on plants. Grasshoppers may appear in clouds that darken the sun and devour every living green plant in their path. Cutworms, living underground, may devastate a farmer's wheat field by pinching off the young seedlings as fast as they sprout.

Insects are also recognized as injurious to man's health, either by direct attack or as carriers of agents of diseases. One familiar example will suffice for both; everyone has experienced the sharp probing mouth parts of the mosquito, and nearly everyone is aware that if the mosquito is carrying the organism of malaria, its bite is infinitely more dangerous.

The third manner in which insects may vitally affect man's activities is as carriers of disease organisms or as agents of plant diseases, and in recent years it has become increasingly evident that some of the most difficult problems of entomology are those in which both insect and plant disease are concerned.

There are three ways in which an insect may be involved: First, the insect may carry on, or in, its body the spores of fungi and bacteria, and contaminate blossoms or wounds on the plant with these organisms. Second, the insect may feed by puncturing the leaf or stem and sucking the plant jucies. In so doing the insect injects fluids into the plant, which facilitate the feeding process, and these fluids may have a profoundly disturbing effect on the plant. In such cases the insect itself is the source of the agent of disease and no organism is involved. Third, the insect may acquire from a diseased plant, and transmit to other plants, minute bodies called viruses, which may or may not be living things.

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[1] Published with the approval of the Director as Miscellaneous Paper No. 30 of the Pineapple Experiment Station, University of Hawaii.

It is obvious that with such diverse possibilities the problems encountered are extremely varied, but in the account which follows, only examples of the principal types are described.

FUNGUS AND BACTERIAL DISEASES

A tiny bark beetle, only one-tenth of an inch long, emerges from a dying elm tree and flies off to feed on the leaves and buds of healthy elms. These beetles are the couriers of death, for on their bodies are the spores of the fungus causing Dutch elm disease, and the trees that these spores infect soon become sickly and diseased. These sickly, dying trees offer a perfect breeding ground for the beetles which burrow between the inner bark and the sapwood and lay their eggs in long vertical galleries. A vicious cycle is thus established which spreads over the forest like the ripples in a pool into which a stone is thrown.

The story of how certain varieties of fig are fertilized through the agency of tiny wasps called *Blastophaga* is well known. It is not so well known that these same insects are the carriers of a serious fungus rot of the fig. The body of the insect as well as its wings are covered with short spines, and it is on these that the fungus spores adhere when the insect pushes its way out through the cavity of a diseased fig. When the insect enters another fig, the fungus spores are carried in with it, and in this manner the disease is spread.

In some cases an insect's intestinal tract becomes full of disease organisms when the insect feeds on the tissues of diseased plants. In addition, therefore, to the infecting of healthy plants by the insect as it moves around from plant to plant, there is the added complication that the insect becomes a reservoir of the disease organisms that are able to live through the winter in the insect, which thus becomes a carrier again as soon as spring brings new activity. Such a case is illustrated in plate 1, which shows corn affected by what is known as Stewart's disease. This disease is caused by a bacterium that is carried to corn by several species of tiny flea beetles, but principally by one species. The disease-producing organism with which the beetle infects the plant overwinters in the insect's body.

The beetle becomes active in the spring when the temperature of the ground reaches 70° F. and attacks young corn as soon as the shoots appear above ground. All of the overwintering beetles do not carry the infection, of course, but by actual test, about 14 percent were found infective. Since an infective beetle remains so for practically its entire life, it is evident that the disease could be widely scattered through a corn field early in the season so that the chance

would be very great that a new brood of beetles would feed on this diseased corn and become infective.

DISEASES CAUSED BY INSECT FEEDING

The transmission of disease organisms is perhaps the simplest way in which insects are concerned in the spread of plant diseases, but there are more subtle and insidious ways that are even more devastating in their consequences. One of the oldest known cases of an insect producing a plant disease by merely feeding on the plant is that of hopperburn of potatoes. Entomologists disagree as to just how the potato leafhopper does it, but there is no difference of opinion as to the damage done to potato plants. Badly affected fields have a scorched appearance, which is due to the fact that the leaf tips are shriveled and brown, and the yields of tubers from such fields are very much reduced.

Some workers believe that the disease is due to a chemical substance injected into the plant along with the insect's saliva, which upsets the delicate machinery of food manufacture in the plant; others consider the explanation a more simple one—merely that the leafhopper, when it feeds, injects so much saliva into the plant that its plumbing system is plugged.

There are other cases, however, which are clearly due to the injection by the insect of some substance which is actually toxic to the plant. In 1927, in the State of Utah, huge losses to the potato crop were sustained on account of a disease which affected the entire potato plant—leaves, stems, and tubers—and since then the disease has been recorded from a number of western States. This disease, called psyllid yellows, which also affects tomato plants, is caused by the feeding of the immature stages of a single species of insect, the tomato psyllid (pl. 2). Just why up to 1,000 adults of the insect can feed on a potato plant without causing the disease while a few immature forms of the same insect can produce typical symptoms and damage, can only be explained by presuming that the adults' secretions when feeding are different chemically from those of the immature forms. There seems to be no doubt that in this case the disease is due to the injection by the insect of a substance, extremely powerful chemically, which spreads throughout the plant and upsets the whole living process. The leaves of a badly affected plant look as though they had been curled with a hot curling iron. The length between the leaf stems becomes shorter so that the plant has a badly bunched-up appearance, while small green tubers are actually produced on the stems above the ground. Underground, many tubers are produced but they are small and commercially worthless.

Mealybug wilt of pineapples is another important example of a disease caused by the toxic injections made by an insect when it feeds (pl. 3). By 1930 this disease had made such inroads that the pineapple industry in Hawaii was in serious jeopardy, and even now control methods must be rigorously maintained. The mealybug, carefully fostered by several species of ant, moves into the pineapple field from the weedy field margins and establishes itself on the pineapple plants on which it feeds. The mouth parts of the mealybug are very long—almost twice as long as the insect itself—and when not being used are curled up like a lasso. Their great length is of value to the mealybug since it can remain in one place on the leaf and yet reach a considerable leaf area with its long probing mouth parts, sucking the juice from particular cells in the leaf.

During the feeding process, and probably as part of it, the insect injects into the leaf some substance which is powerful enough to pass down the leaf to the roots and kill them. The natural consequence of this is that the plant wilts down in a manner very similar to wilt due to extreme drought. In this stage the plant is low in sap, and the mealybugs leave it and move on to adjacent healthy plants. These in turn wilt and the process goes on until, without control measures, a field may be ruined. When the mealybugs have left a plant, new healthy roots are put out and the plants makes a gallant effort at recovery. If wilt has occurred while the plant was only a few months old, worth-while recovery sometimes occurs, but usually the fruits are too small to be of commercial value. Recovery is of principal interest in demonstrating that the removal of the mealybug and, with it, the toxic substance it injects, results in new wilt-free growth.

Psyllid yellows and mealybug wilt are cases in which the effect of the injected toxin is general throughout the plant affected, but the more common examples of the toxic effect of insect feeding are the almost innumerable cases where the effect is localized to a very small area around the actual feeding point of the insect or, at most, a short distance away. The stippling effect on leaves fed upon by leafhoppers, the spotting of leaves by the scale insects and mealybugs, and the curiously varied symptoms produced by the so-called mosquito bug on tea and many other crops, are all cases in point, but only the last-named can be discussed here.

The mosquito bug is not even related to the mosquito, but derives its name from its general appearance—long narrow body and unusually long legs and feelers. Actually it is one of the sucking plant bugs of which the chinch bug is a better known example. The list of plants which the mosquito bug affects is noteworthy because of the extremely diverse symptoms which result. Typically, a red spot on the leaf follows the insect's feeding. This spot dies and withers. In

some cases the spot is visible before the insect has finished feeding, indicating that the feeding process is a very vigorous one. On tea, it has been estimated that six mosquito bugs, during their development, can destroy a pound of green leaves.

The typical spot occurs when the insect reaches certain cells in the plant. If other cells are reached, then different symptoms result. For example, on mango fruits, if the mouth parts of the insect reach the middle skin, scab symptoms occur, while if the inner skin is reached, rot results. On the stems of mango and tea, cankers formed by split and swollen bark result if the mouth parts reach certain other cells.

In most cases where sucking insects cause local disturbance in the leaves of plants, it is possible to trace the route that the mouth parts took, because in penetrating the leaf tissue the insect injects a kind of saliva which hardens in the leaf to form a well-defined track. It is thus possible to learn whether the insect pierces directly through cells in a direct line to the particular cells which are its objective, or whether the objective is reached by a tortuous course between the plant cells.

One case is known where one strain of an insect species produces a local spotting while another strain does not. There are two strains of the pineapple mealybug, and one of these produces a dark green circular spot at the point where the insect feeds on the leaf.

THE VIRUS DISEASES

The virus diseases constitute the third great division of plant diseases that are spread by insects. This is perhaps the most important group of diseases of plants carried by insects, although this statement would be difficult to prove in the absence of actual comparative figures on the damage caused. The number of plant viruses known is very large, at least 100 being recognized apart from numerous variants which are known as virus strains, and new ones are continually being recognized and described.

There is considerable debate at the present time as to whether viruses are living things or highly complex chemical structures with some characteristics similar to those usually associated with living matter. Since this paper is primarily concerned with the role of insects in spreading these agents of disease we can proceed on the basis of what is universally agreed upon, namely, that whatever their true nature, viruses are spread principally through the agency of insects.

The number of plant species affected is very large. The virus of tomato spotted wilt is known to affect over 100 species of plants; the virus of curly top of sugar beet, a disease that has been studied in great detail for many years, has over 200 known plant hosts; aster

yellows virus is known to occur in more than 180 separate plant species. Some viruses are known to affect only 1 species of plant, but by far the greater number are known from more than 1 host.

Needless to say, the symptoms of the diseases caused by these viruses vary greatly, from the alternate light and dark green patches of the well-named "mosaic" diseases, to the bizarre patterns of a group of viruses generally known as the ringspot viruses because of the ring-shaped spots, often showing a pattern of concentric rings, which appear on the foliage of affected plants.

The insects concerned in the spread of viruses are almost all sucking insects, and of these, the aphis or plant lice are the worst offenders, with the leafhoppers another very important group. The discovery that the thrips are also carriers of virus disease is of much interest because thrips feed by first tearing the leaf tisue and then sucking the exuding juices; the aphis and leafhoppers penetrate deeply into leaf tissue, but the thrips are shallow feeders.

WORLD-WIDE EXTENT OF THE PROBLEM

The occurrence of insect-transmitted diseases of plants is world-wide, and wherever agriculture is practiced, from the wheatlands of the north to the equatorial Tropics, the problem presents itself in one way or another. Even greenhouses are not exempt; in fact, because of their usually protected conditions they sometimes give opportunity for a disease-bearing insect species to survive far out of its normal geographic range. Specific problems are often regional because the insects concerned have a restricted geographic range. whereas others, because the insects are cosmopolitan, are world-wide. An example of the first type is the transmission of curly top of sugar beets and other plants by the sugar beet leafhopper. Roughly speaking, [illegible] insect is confined to the great semiarid regions of the intermountain region and California. Years before it was known that a serious disease of tomatoes was caused by the same virus which causes curly top of sugar beets and was transmitted by the same insect, it was realized that the geographic range of the two diseases was the same. Isolated from the curly top of the western United States by a whole continent, and similarly restricted to a specific insect's range, is a disease of sugar beets in Argentina which is so similar to curly top as to be practically indistinguishable, yet it is transmitted by another species of leafhopper and appears to be a distinct disease.

An example of the second type is that of spotted wilt of tomato. This virus disease, which is transmitted by certain species of thrips [illegible] now known to be world-wide although the disease has been desc[illegible] under several names in various places. It was first rec[illegible] on Australia; later in English greenhouses. Independently c[illegible] In

studies in Hawaii revealed a disease of pineapple which is thrips-transmitted and which is called yellow spot. Another study in South Africa described a disease of tobacco called kromnek (crooked neck) disease. Workers now realize that they are all dealing with the same disease, either on tomato or on other economic species of plants that are attacked (pl. 4).

Mealybug wilt of pineapples appears to be present wherever a susceptible variety of pineapple is grown and mealybugs are present in any numbers. The mosquito bug has been recognized as a serious pest of tea in India and Java for many years, but the same insect is now known to affect not only tea but many other crops in inland Africa. A virus disease of cassava, which is a staple starchy food of many native peoples, is known throughout tropical Africa and in Java (pl. 5). On the other hand, the virus diseases of Irish potatoes are world-wide, and it is doubtful whether potatoes absolutely free of virus diseases are to be found anywhere.

HOW THE INSECT ACTS AS A CARRIER

Reference has already been made to the spread of fungus and bacterial diseases. Usually the organisms of these diseases adhere to the insect's body and are carried from blossom to blossom and from leaf to leaf or tree in that way. In some cases the organisms are taken into the intestinal tract of the insect and develop and reproduce there.

The toxic effects of insect feeding depend on the sensitivity of particular species of plants to the injections of specific insects. Some insects, such as the potato leafhopper and the mosquito bug, affect many species of plants, but with each plant species reacting in a somewhat different way. The pineapple mealybug, however, although it lives and flourishes on many kinds of plants, from short field grasses to bananas, produces wilt disease symptoms on only one, the pineapple.

The actual toxic principal has not been isolated from any insect associated with this type of disease for the very good reason that the insect's salivary glands, which are presumably where the toxic substances arise, are extremely small and their contents very unstable chemically. There has been a measure of success with experiments on the injection of whole salivary glands in some cases but the isolation of the toxic principles themselves is probably beyond the capacity of even modern analytical technique.

The manner in which insects acquire and spread virus diseases of of plants has been studied in great detail, subject to the important limitation that, since the virus itself cannot be seen in the insect's tis- [illegible] the appearance of disease symptoms in the plant fed upon is the great[illegible]ion which the experimenter can use. In simple outline, the [illegible] whereby an insect acquires and transmits a virus is as follows:

The insect feeds on a virus-diseased plant and moves over to a healthy plant, at which point one of two thing may happen. The insect may inoculate the plant with the virus at once, or a period of time varying from a few hours to many days may elapse before the insect is capable of transmitting the virus. In either case there is a period of development in the plant before disease symptoms occur.

Generally speaking the insects capable of transmitting a virus without any delay are the aphis or plant lice and those that transmit viruses only after retaining them in their bodies for a long period are the leafhoppers and thrips. There is a certain compensation, however, for the long delay, since the aphis can usually only inoculate one plant, whereas the leafhoppers and thrips can inoculate a long series of plants, often throughout their remaining life.

The period of time which the virus must spend in the insect has been called the incubation period because it was assumed that during that period the virus developed, i. e., reproduced to a point where it could be injected by the insect in sufficient quantity to establish the virus in the plant. Recent work has challenged this point of view however, and it is doubtful whether many viruses multiply in the insects' bodies at any time.

The matter has by no means been settled, however, since much of the evidence for multiplication has not been satisfactorily explained away. There is, for example, a virus disease of rice in Japan which is transmitted by a leafhopper. This virus passes through the eggs of the virus-carrying female, and experiments have shown that leafhoppers can thus acquire the virus from their maternal parents. A family of these leafhoppers can therefore be carrying the virus even though their grandparents were the original feeders on the diseased plant. This is considered real evidence for multiplication because otherwise the original quantity of virus would have been diluted to a degree which no known virus can stand and yet remain capable of infecting a plant.

The path of the virus in the insect's body is, of course, only a matter of surmise although there is experimental evidence that it enters through the mouth and passes to the midintestine and out through the wall of the midintestine to the blood, in which it is carried to the salivary glands, whence it passes out with the salivary secretion injected by the feeding insect.

It is a matter of great interest to learn just where in the insect's body the virus is stored, for if it does not multiply in the insect, it must be held in some tissue from which it is gradually released. The best evidence thus far is that the blood is the reservoir for the virus. Certainly viruses have been found in insect blood, for by employing ingenious techniques blood has been removed from virus-bearing in-

sects and fed to nonvirus individuals, which in turn have transmitted the virus acquired in this way to plants.

It might well be asked why some sucking insects feeding on a virus-diseased plant acquire and transmit the virus while other species feeding on the same plant do not. It is true that many viruses are transmitted by very few species of insects, others by only one, whereas some insects can transmit many viruses. The leafhoppers as a group transmit the viruses with a very restricted transmission, the plant lice the less restricted. The peach aphid is known to transmit 21 viruses, many of which can also be transmitted by other aphid species. On the other hand the leafhopper-transmitted viruses are usually limited to a single species of insect, though there are a few exceptions.

Many species do, however, take up a virus when they feed on diseased plants although they are unable to pass the virus on to other plants. In some of these cases, the midintestine acts as a barrier and instead of passing through into the blood the virus passes on and is ejected with the insect's faeces. In other cases, viruses have been shown to pass through the intestine into the blood of nontransmitting insects, so some other barrier, possibly the walls of the salivary glands, acts to prevent the virus from passing out into the plant during the process of feeding.

It is difficult to see any but purely academic interest in these relationships between insect and virus, but workers in this field feel that if these relationships can be explained, then the nature of viruses, whether living or nonliving, may be explained also. It is true that a few viruses have recently been purified and concentrated into what appear to be purely chemical bodies which are proteins. In this state they can be measured, weighed, and their physical and chemical characteristics determined. To those who believe that measurement is the alpha and omega of science, this evidence suffices, but it would be premature to suppose that the last word has been said. Perhaps the safest view to hold in the interim is that while certain viruses, not particularly notable for their close relationship with insects, have been "purified," the viruses having close and seemingly obligatory relationships with their insect carriers have not been, and the most tenable explanation is that the word "virus" as used thus far covers a number of closely allied but different categories. Whatever may be the actual nature of viruses the fact is not altered that the diseases they cause in plants are still with us.

THE EFFECTS OF CLIMATE AND WEATHER

Climate and weather exert an important influence on insects in general and on insect transmitters of plant diseases no less. Climate, being a general expression for all the weather encountered over a relatively large region, governs the distribution of many insects.

Weather, being the day to day expression of climate in that region, vitally affects both numbers and activity of the insects living in the region. But even weather is subject to an almost infinite number of variations due to extremely local conditions, and as far as an insect is concerned, the weather on the outside edges of a bush may be quite unfavorable compared to that within the confines of the same plant.

With regard to climatic influences, the case of curly top of sugar beet and the beet leafhopper is a well-studied example. This insect is distributed over a vast area bounded roughly by the Rocky Mountains on the east and the dry interior valleys of California on the west. To the north and south it appears to extend as far as dry, semiarid conditions hold. The climate is characterized by spring and fall rains and hot, dry summers and by great variation in winter weather from year to year. The insect overwinters near the annual weeds that germinate in the fall, and in the spring breeds freely on these plants. When these short-lived weeds mature, the leafhoppers migrate and disperse over huge areas seeking new feeding grounds. It is this dispersal which brings disaster to cultivated crops for when the uncultivated, unirrigated lands are dried up, the lush green irrigated sections are oases for the flying leafhoppers which in some years arrive almost overnight in enormous numbers. It is during these great flights that occasionally the leafhopper is carried by wind currents far beyond its normal geographic range and instances have been recorded of finding curly top of sugar beet in the Dakotas. If the climate of the Midwest, with its summer rains and severe winters, would permit the survival of the sugar beet leafhopper, there is no doubt that the insect would long since have established itself there as a serious pest.

In its home range, the migrations of this insect are greatly affected by weather which shows extreme variations from year to year, and these variations are sufficient to make the difference between a year of early and extensive migration and a year where, except for minor flights, the bulk of the leafhopper population remains on the desert until too late to do serious damage to crops. These differences are governed by the condition of the insect's weed host plants. An early warm and dry season will hasten the maturity of both the new brood of insects and the plants, so that before the plants that normally carry the insect through to summer are growing, the early host plants are dry and unsuitable for food. Variations in the severity of the winter also affect the survival of the leafhoppers to a marked degree, a severe winter materially reducing the numbers that are available for reproduction in the spring.

An adequate study of such a problem involves detailed investigation over vast stretches of country. Breeding grounds of the leafhopper must be located and the life history of the insect studied there. Great areas of desert must be traversed to determine the presence of the

insect and the appearance of the new brood, for it is when this brood matures that the danger period is at hand and flights into cultivated fields are likely to occur.

In the beet leafhopper problem, the weather conditions over individual areas perhaps 200 miles long are significant. In Africa, where a virus disease of the peanut is sometimes serious, weather is also important but in an extremely localized way. There is a story told which may be apocryphal, but which has a substantial basis as far as the scientific data are concerned. A director of agriculture in an African colony, wishing to improve the native methods of culture of peanuts, arranged to have demonstration plots planted to show the natives that their method of crowding the plants together was wrong. When the crops were grown, however, the nice, orderly, well-separated official plants were badly diseased, while the native plantings escaped with only minor damage. The explanation, which seems to be well authenticated, is that the more open plantings permitted freer air movement, which increased temperature and light and reduced moisture around the plants. These changed conditions were enough to favor the activity of the insect carrier of the peanut mosaic, which is an aphid. The native knew through long trial and error that his method worked, but the investigator, looking for the reason, had to have recourse to delicate measurements of extremely local weather in a very limited environment.

The old cartoon concept of an entomologist was of a bespectacled individual waving a huge collecting net, but Welsh and Cornish farmers have recently been treated to the sight of men tramping through their fields, swinging not nets but thermometers, measuring humidities and wind velocities and collecting not butterflies but plant lice; and doing all these things because the potato crop depends on good disease-free seed.

The seed-potato business in the British Isles has been almost a monopoly of certain Scottish districts where potatoes have enjoyed freedom from the virus diseases. In recent years, however, these diseases have become established there and the desirability of finding new districts where disease-free seed could be grown has led to a careful study of potato-growing areas to determine the reasons why potato plants are free from the disease in some locations and severely affected in others in the same district. It was found that the principal plant lice species that carry potato viruses are very sensitive to a combination of wind movement and air humidity and that fields subject to the right combination of these two factors were likely to be affected only to a very slight degree. This is one of the most recent and best illustrations of how a knowledge of an insect's reactions to extremely small variations in the weather has led to important practical results.

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Sometimes an artificial condition will permit the survival of an insect far out of its normal range, as seems to be the case in Central Alberta in connection with potato psyllid. An outbreak of psyllid yellows was traced to a greenhouse where the insect had overwintered on tomatoes and moved out into nearby potato fields in the spring. Also there appears to be a greenhouse strain of the onion thrips in England which carries the spotted wilt virus while the ordinary field strain does not.

CONTROL METHODS

Many of the complicated interrelationships between insects and the diseases they carry or cause to plants are vitally affected by the conditions in their immediate environment and this fact is sometimes useful in control measures. It will be obvious, however, that such a diverse set of problems as are presented by insects in their transmission of plant diseases will require most varied attempts at control. Control may be directed at the insects themselves or at the organisms they carry, but there is no standard method of control even in closely related cases.

Field sanitation helps to remove diseased plants and fruits and may thereby reduce the numbers of disease organisms. Complete eradication of diseased elms is believed to be the only possible way to eliminate Dutch elm disease. Diseases such as potato hopperburn, psyllid yellows, and mealybug wilt are all controlled by reducing the number of insects, since damage is directly proportional to the number of insects present and the amount of feeding they do. Control may be by sprays or, in the case of the potato leafhopper on alfalfa, by timing the cutting schedules so as to disturb the insect's reproductive cycle as much as possible.

When long experience and study have shown that certain sets of weather conditions are followed by outbreaks, it is sometimes possible to predict these outbreaks in advance. This does not, of course, control the outbreak, but it does help farmers to avoid losses because in years when outbreaks are expected they can plant other nonsusceptible crops. This was done in a sugar beet curly top district in Idaho from 1927 to 1933, and in these 7 years the prediction failed only once. The necessity is no longer present as far as sugar beets are concerned, but other susceptible crops are grown for which prediction of outbreaks might prove useful.

The real control for the sugar beet leafhopper problem, whatever the susceptible host is, has been visualized, but the concept is so magnificent as to appear impossible of attainment. The vast breeding grounds of the leafhopper are areas which originally were covered with wild grasses and shrubs. These were disturbed by overgrazing and attempts at dry-land farming, and in their places weeds that are breeding plants for the leafhopper have come in and occupied the

land. If, by control of grazing, the original plant species could be restored, then the vast area at present devoted to weeds would once more be restored to usefulness and at the same time the source of most of the leafhoppers would be eliminated.

If the sugar beet industry in the West had had to rely on this program, however, it would have continued to decline. Why then has it increased in size and productiveness? The answer is because disease-resistant beets have been sought and found (pl. 6, fig. 1). This has been the work of many men in many places, but the net result is one of the most successful in the history of science in agriculture. Many other efforts are being made to produce plants resistant to virus diseases, because in these cases merely reducing the numbers of insects does not seem to help very much. An insect pauses for a moment to feed on a plant and that plant becomes diseased whether the insect stays there or not. If the disease-bearing insect can be kept from reaching the plant at all, then control is possible. Aster growers, for instance, can get a considerable measure of relief by protecting their aster beds with a low screen fence. The aster yellows leafhopper is not a migrant on the grand scale like the sugar beet leafhopper, but rather a low-flying species which can be kept out by means of screens which would not affect the sugar beet leafhopper in the least.

A somewhat similar control method is used in Java against the mosquito bug on tea. This insect belongs to the group that could be controlled by sprays, but a Java tea plantation looks like a huge forest with the tea plantings as a solid undergrowth, and spraying is not practicable. The control used there is based on the fact that the insect is shy and retiring and does not cross open spaces willingly. When the tea plant is pruned, therefore, the pruning is done in alternate strips so that the insect tends to remain in the unpruned portion instead of spreading over the whole plantation. Although this is avoidance rather than control, the method has proved its usefulness in reducing damage (pl. 6, fig. 2).

The most recent method of control is being used in connection with some tobacco viruses. It has been found that some viruses which do little damage to plants inoculated with them, nevertheless protect the plant against other more damaging viruses. This protective inoculation offers much promise, but there is one apparent danger in that some viruses, when found in plants with other viruses, cause damage far more severe than when they attack the plants singly.

THE OUTLOOK FOR THE FUTURE

Certain trends may be recognized which may indicate what future developments will be. First there is a definite move toward compilation of scattered data into summaries and textbooks; a part of this trend is the attempt to set up formal classifications. Once a beginning

has been made with classification, new cases that arise can often be placed at once in their proper categories, while the inevitable debate that centers around the doubtful cases often leads to the suggestion of new experimental approaches.

In the case of the fungus and bacterial diseases the problem is primarily one of determining under what circumstances the insect becomes a carrier. The insects whose feeding secretions are responsible for plant diseases present much more difficult problems, but these fall into perhaps two general categories: What is the nature of the secretion and how does it affect the plant's physiology, and, What factors of insect nutrition and plant susceptibility are involved?

The trend in virus research is unmistakable. The nature of the virus, whether living or nonliving, will continue to occupy the attention of workers for a long time. All viruses may ultimately be classified as nonliving proteins with some of the characteristics of crystallinity, but there is a possibility that the viruses as we now define them may include both living and nonliving things as well as those on the borderline between highly complex chemical molecules and living matter. This is an exciting prospect for those whose privilege it is to pursue knowledge for its own sake and important for those whose services are devoted to the control of virus diseases. The general problem is so complex, however, that workers in very widely separated fields of study are involved. It is a far cry from a farmer's field to the microscope specially designed to reveal the structure of crystals, but workers in these two fields must somewhere get together if the problem is to retain its fundamental unity. The entomologist is in a position to make material contributions to the problem by adding to our knowledge of the relationship between insects and viruses.

Investigations on control methods will continue to follow as diverse lines as heretofore. Fungus and bacterial diseases will probably be attacked by reducing the numbers of the insect carriers and eliminating sources of infection. The diseases caused by the toxic secretions of insects will continue to be controlled by reducing the numbers of insects, but there is a promising line of attack in learning what factors make a plant susceptible to this sort of injury. It might then be possible to reduce this susceptibility by cultural or other methods.

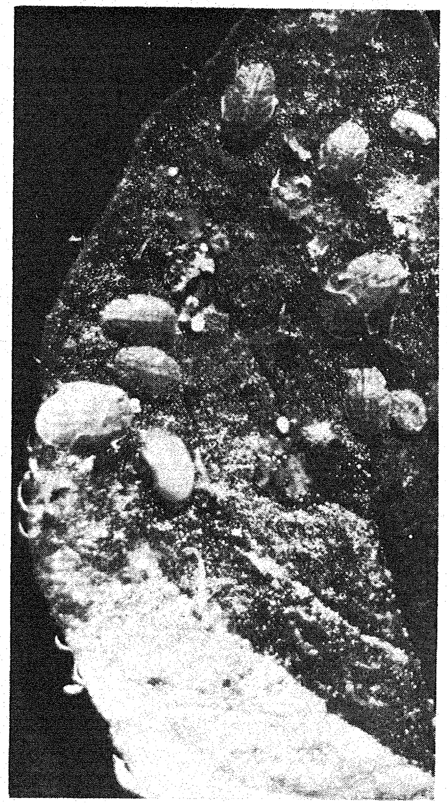
Some progress has been made in breeding plants, not only for resistance to organisms and viruses but also to insect attack. This offers promise as a part solution of the problem, but resistance to the virus seems to be the most fruitful line of attack on the immediate problem of how to reduce losses by virus diseases. Protecting plants against viruses by inoculation with other viruses is a fascinating prospect even though fraught with many complications. Finally there is the possibility that chemical treatment of plants to protect or cure them of infection may become a reality.

BACTERIAL WILT OF SWEET CORN.

Plant at right killed by the disease; plant at left, healthy. Photograph by Bureau of Plant Industry, U. S. Department of Agriculture.

1. A POTATO PLANT SHOWING ADVANCED STAGES OF PSYLLID YELLOWS.

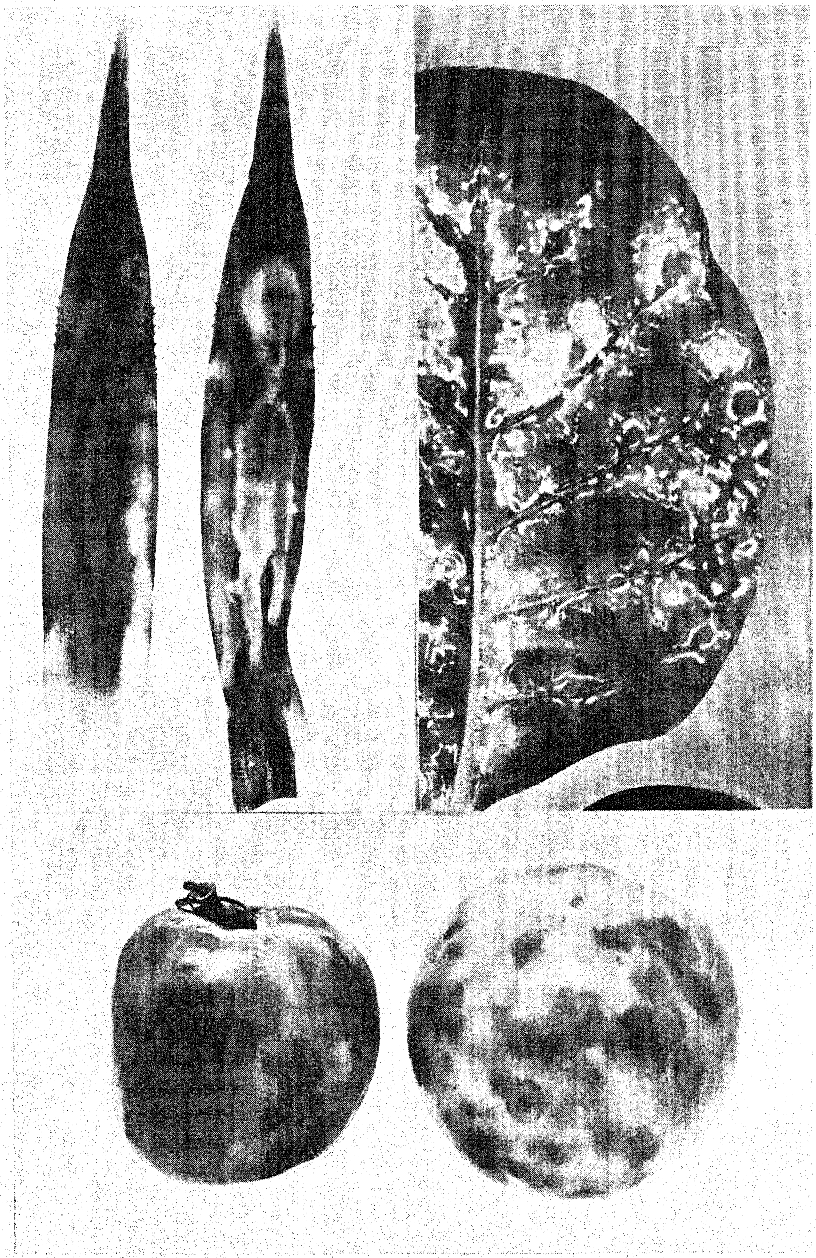
Note the curled leaves and bunched-up appearance of the plant. Photograph by B. L. Richards.



2. IMMATURE STAGES OF THE POTATO PSYLLID ON A POTATO LEAF.

Photograph by B. L. Richards.

MEALYBUG WILT OF PINEAPPLE PLANTS.



SYMPTOMS OF TOMATO SPOTTED WILT ON DIFFERENT HOSTS.

Upper left, yellow spot of pineapple. Photograph by M. B. Linford.
Upper right, symptoms on White Burley tobacco. Photograph by K. Sakimura.
Lower, tomato fruits with typical ringspot symptoms. Photograph by K. Sakimura.

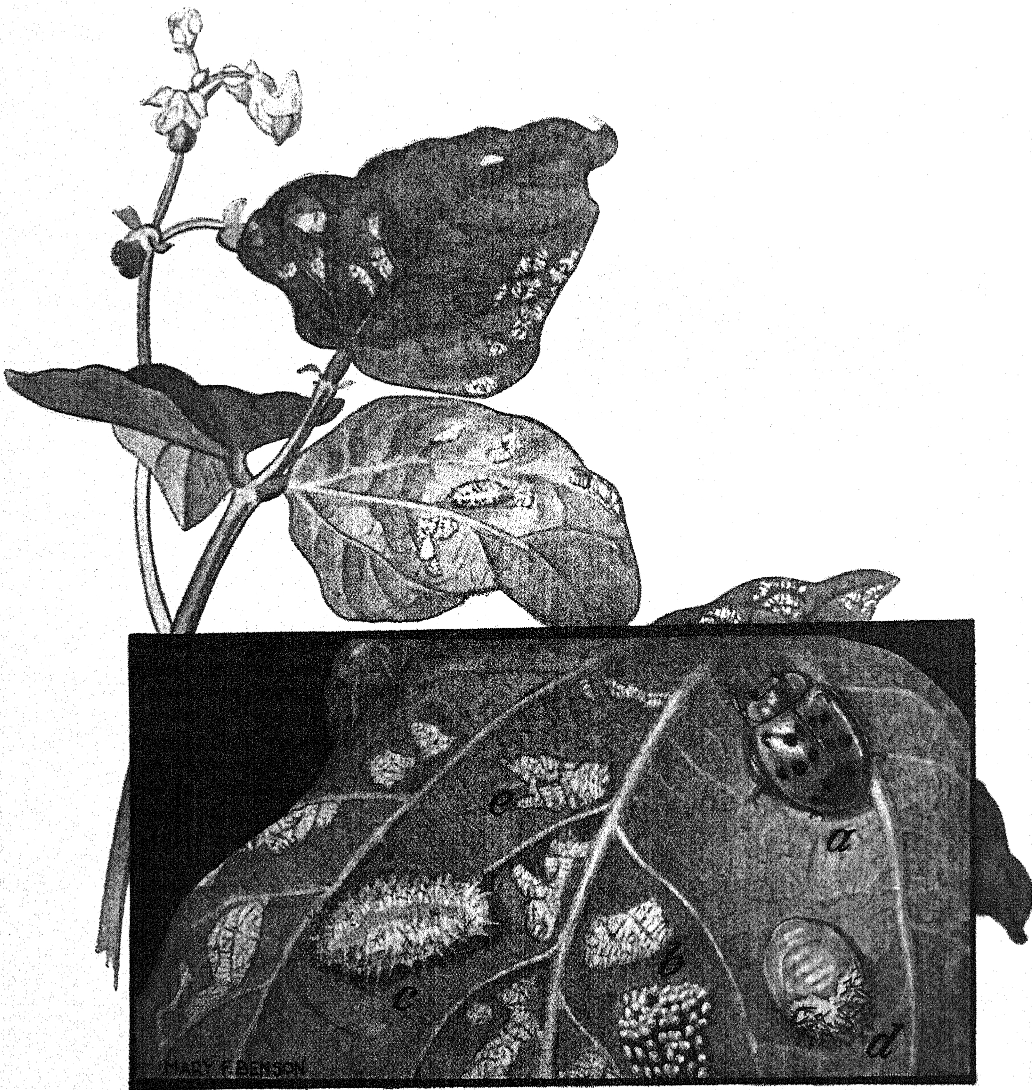
CASSAVA MOSAIC DISEASE.
Plant on right is healthy; that on the left, diseased.

1. A TEST OF CURLY TOP RESISTANT BEETS.

The dark strips are U. S. No. 1 resistant variety which yielded 13.6 tons per acre. The light strips are a susceptible European variety and yielded 2.5 tons per acre.

2. STRIP PRUNING OF TEA PLANTS TO LOCALIZE INFESTATIONS OF MOSQUITO BUGS.

The recently pruned strip is in the center of the picture; the unpruned plants in the background and right foreground.



MEXICAN BEAN BEETLE.

a, Adult beetle; *b*, eggs; *c*, larva; *d*, pupa (or resting stage) *e*, bean leaf showing typical feeding injury. (About 2½ times natural size.)

THE MEXICAN BEAN BEETLE [1]

By W. H. White

Bureau of Entomology and Plant Quarantine, United States Department of Agriculture

[With 6 plates]

INTRODUCTION

In 1920 a black-spotted copper-colored beetle was discovered on garden beans in the vicinity of Blocton and Birmingham, Ala. It was readily recognized by the entomologists as an insect known at that time as the bean lady-beetle, an immigrant from the West, an immigrant whose presence was viewed with alarm because the insect had been long recognized as a destroyer of garden beans in the irrigated regions of the southwestern States. As early as 1883 Prof. G. H. Stone of Colorado Springs, Colo., in a letter to C. V. Riley, Entomologist of the United States Department of Agriculture, dated August 26 stated:

> By this mail I send you a tin box containing larvae and perfect beetles which promise to have almost as unenviable a reputation as *Doryphora 10 lineata* [the Colorado potato beetle which spread across the country from the West toward the East and destroyed the potato crop during the period of from 1824 to 1874]. From the egg to the grave they are voracious. They are good judges of food. With me they have confined their attacks to black wax beans, and the enclosed leaves and pods will show their mode of attack. The early broods attack nearly all kinds of vegetables in a neighboring garden. They are rapidly spreading in the vicinity. I judge there are two or three broods in the year like Doryphora—they only appeared in my garden a few days ago. Within that time they have eaten almost every leaf in a good sized patch of wax beans.

Stone's letter to Riley was apparently not the first record of the occurrence of the bean beetle as a destroyer of beans as F. H. Chittenden, of the United States Department of Agriculture, quotes a letter from a correspondent from the West, dated 1889, in which it is claimed that the beetle "had been known by its injuries at Watrous, N. Mex., 40 years earlier than the date of writing." This date, being close to the Mexican War of 1846–48, led Chittenden to conjecture

[1] *Epilachna varivestis* Muls.

that its presence in the United States might have resulted from the movement of food for the cavalry during these military operations. However, with the now well-known ability of this insect to spread under its own power, Arizona, New Mexico, and Colorado may have been infested long before this time and even before white man found his way into the region. However, the facts that Mulsant first described the beetle in 1850 from specimens received from a collector in Mexico, that Bland in 1864 redescribed the species from specimens taken in Mexico, and that related plant-feeding Coccinellids are foreign to the United States, with the exception of one, indicate that the bean beetle's original home was "south of the border."

Irrespective of its original home, war seems to have marked the two significant dates of its importance in the United States, as its occurrence in Alabama has been also attributed to the movement of large shipments of alfalfa hay from the West into northern Alabama during 1918. This year may have been the actual date of its introduction into the Southeast, as authentic reports by various growers indicate that the pest was not uncommon about Birmingham, Ala., in 1919.

Even in the light of the early knowledge of this pest's severe attacks on beans in certain regions of the West, it does not appear that any apprehension was felt as to its gaining a foothold in the eastern States. At any rate the literature does not reveal that any steps were taken to prevent its introduction into the East. Although Stone in 1883 predicted for this beetle almost as unenviable a reputation as the potato beetle, it was almost 50 years later before the bean beetle established its reputation as a major pest of the bean crop of the East, and then it came to the East as a "stowaway," and not by natural spread as did the potato beetle.

With its discovery in Alabama the agricultural interests of the South became alarmed and urged the Federal Government to lend assistance in coping with the problem. The alarm felt was justifiable, as during the second year of its occurrence in the East the insect was so destructive in the Birmingham, Ala., area that the price of green beans rose in some instances to four times their normal value. To increase the apprehension were the facts that the insect multiplied and spread rapidly in its new habitat and little was known of its ability to destroy other crops belonging to the same botanical family, so important to the agriculture of the South and East, such as cowpeas, soybeans, and even the clovers.

SPREAD

The rapidity with which the beetle spread in a general northeasterly direction was remarkable. By 1930, 10 years after its discovery in Alabama, it had become a familiar sight to the bean growers, both

commercial and home, in the States of the East from Georgia to Maine and westward to Illinois. The bean, the favorite planting of every garden, which had been quite free of insect injury until now, appeared to the grower to be destroyed overnight by a lemon-colored fuzzy

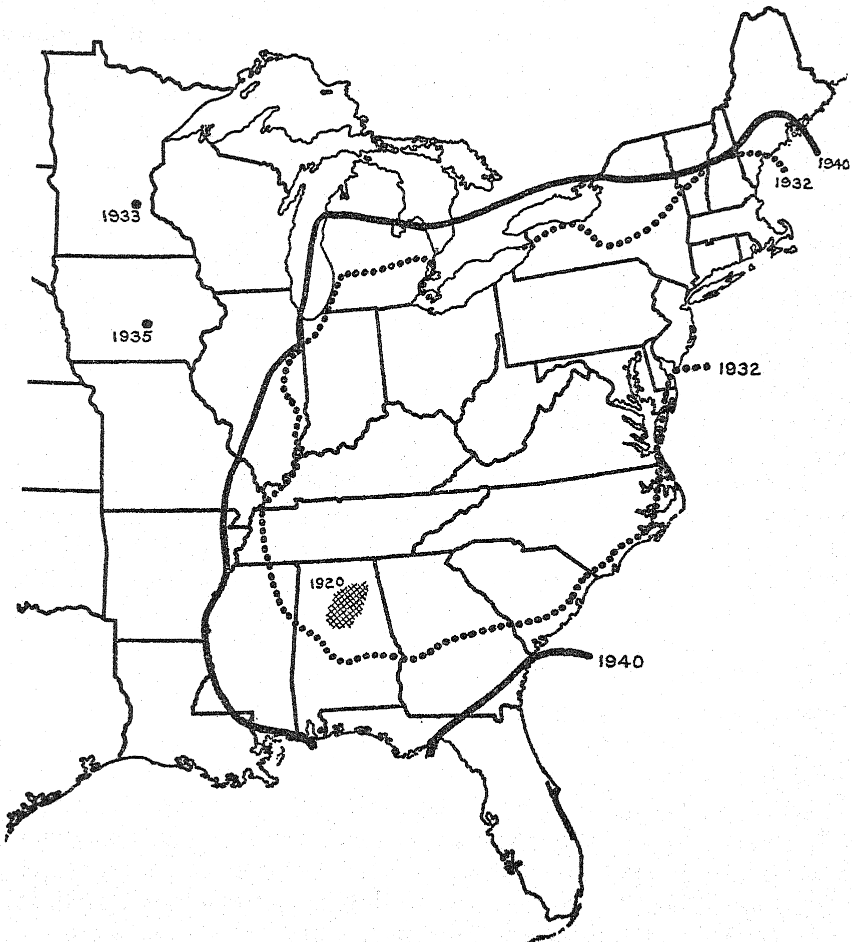


FIGURE 1.—Map outlining area known to be infested by the Mexican bean beetle, *Epilachna varivestis* Muls. Cross hatching, original infestation, 1920; dotted line, infested area up to 1932; unbroken line outlines the area known to be infested by the season of 1940; dot in Minnesota and Iowa shows location of isolated infestations in 1933 and 1935 respectively.

creature, the immature stage or larva of the beetle. It was called by one the "yellow peril."

A survey in 1920 revealed the presence of the beetle over a contiguous area approximating 4,500 square miles in the vicinity of Birmingham, Ala. In 1921 the infested area had been increased by approximately 40,000 square miles, mainly in a northeasterly direction northward

beyond the border of Tennessee and eastward through Georgia into the northeast corner of South Carolina with an isolated infestation in the vicinity of Thomasville in southern Georgia.

Its distribution in 1922 was known to have increased 70,000 square miles, principally westward and northward with a slight increase in the infested area to the southwest. The annual distribution outlined herein for the subsequent years is based upon records of its discovery in new areas as reported by entomologists and growers and others, and is not the result of a planned survey as was the case during 1921 and 1922. Reports received in 1923 showed an extension of invaded territory of approximately 26,500 square miles, mainly northward with no additional territory to the south or west reported as infested.

In 1924 the beetle had extended its range, 85,500 square miles of newly infested territory being reported from all directions. This was the most extensive distribution reported for any 1 year during the 20 years it has been known to occur in the East. Again, as was the case in former years, the greatest spread was to the north, reaching into Ohio almost to Lake Erie and eastward into the southwest corner of Pennsylvania.

During the next 2 years the records of new infestations were unusual in two respects: The additional square miles reported infested were comparatively small, considering the large territory now infested from which the insect could spread, and the spread extended to the east and west only, no new territory being invaded in the south or north. In 1925 additional reports came only from east of the infested area.

The factors which influenced the reported slower advance of the beetle into new territory during 1925 and 1926 were absent the following year. In 1927 the beetle was found to have reached the shores of Lake Erie in southwestern New York and was reported from Canada. It now threatened the great bean-growing area of Michigan and was present on the Atlantic coast in southeastern Virginia. Westward, however, the spread was confined to a narrow strip in Tennessee, Kentucky, and Indiana. The total extension of its range during the year was 80,000 square miles and this spread was the second greatest in its history. The spread in 1926 was confined to about 56,000 square miles and was notable because the market and canning bean-growing sections of eastern Pennsylvania, New Jersey, Maryland, and Delaware were invaded.

After 1928 the insect's spread during each of the following 4 years, judging from the reports, amounted to an average annual increase in its range of about 20,000 square miles. By 1930 and 1931 it had reached the Mississippi River in Kentucky and had moved farther in a northeasterly direction into New York and Connecticut. In 1932 it was found on the eastern border of Illinois and to the west of northern

Indiana and southwestern Michigan. This year was also featured by reports of its advance beyond the center of New Hampshire into Maine to the Atlantic coast. Its spread since 1932 has been limited, apparently having by this time reached the areas most suitable for its survival in noticeable numbers. An isolated infestation was found in Minnesota in 1933 and in Iowa in 1935 but judging from the record the beetle has been unable to thrive in these locations.

The spread of this insect, as given from year to year, can be considered unusually dependable, because of the universal practice of planting beans by the farmer and home gardener. With every agriculturist vitally and personally interested, reports as to the progress of the beetle were received, thus providing a more accurate picture of the spread of the pest than would have been available had the insect been a depredator of some less popular crop.

The entrance of the beetle into new territory was usually attended, in many areas, by a severe loss to the bean grower. The home gardener was probably the greatest sufferer. Now, suddenly, the gardener found his bean plantings ravaged by an unfamiliar pest which he was totally unprepared to combat, and so severe was the damage that in many places the growing of beans in the home garden was abandoned. The destruction came to the grower with a sudden force since the habits of the insect are such that its feeding, being confined to the under surface of the leaves, escaped notice until the damage was done, and the bean patch upon which the gardener had counted became, apparently almost overnight, a scorched and wasted ruin.

Fortunately, as is true of most insects, the impact of the initial influx was not repeated each year. In the following years severe damage was intermittent in nature, and the gardner was able to marshal his defenses and protect his crop either by insecticidal control or by selecting a planting date which would avoid injury. The bean beetle has now assumed the status of many of our common pests—a pest the grower must be on guard against but one which is not viewed with such alarm as when its character was not so well known. Undoubtedly, however, the presence of the bean beetle has reduced the home planting of long-season varieties of beans such as the pole and lima.

In their efforts to control the bean beetle, many materials were tried by the growers, and belief in the efficacy of certain materials and methods still persist, even when the fallacy of this belief has been demonstrated. A case in point is the use of epsom salt, which was recommended by local sages for the control of the bean beetle. When reports as to the efficacy of this material reached the Department of Agriculture, experiments were conducted which conclusively demonstrated that this material is of no practical value for the control of the bean beetle.

Even more strange is the method that was practiced rather extensively in one section of the East and that has also been reported as being practiced in the West. This method consisted of placing tin cans on poles about the field. The origin of this method is obscure, but it apparently caught the popular fancy and for a few years bean fields with poles topped by tin cans were a familiar sight in sections of Maryland and Virginia. One enterprising oil dealer capitalized the popularity of this method by offering a prize to the grower whose bean field presented the best display of cans which had originally contained his brand of oil.

BIOLOGY AND CONTROL

A Federal field laboratory was established in Birmingham, Ala., in 1921, with Dr. N. F. Howard as its director, and in cooperation with the State of Alabama an extensive investigation of the beetle and its control was initiated. The investigations by the Federal Government were continued on a large scale for about 10 years, diminishing in extent thereafter until the year 1938, when they were limited to a study of the pest in the Norfolk, Va., area. The curtailment of this work by the Federal Government was due primarily to the success of control measures developed by Dr. Howard and his staff of workers, namely, L. W. Brannon, H. C. Mason, B. J. Landis, Rodney Cecil, J. R. Douglass, and others.

As the beetle spread, State investigators devoted considerable time to the problem, and the Federal laboratory at Birmingham, Ala., was moved to Columbus, Ohio, in 1926, so as to be located nearer the center of the infested areas. Field laboratories were also established at Geneva, N. Y., in 1924 and at Norfolk, Va., in 1929. Scientists were dispatched to Mexico in 1921–22 in search of parasites or other natural enemies, and a laboratory was established in Mexico City in 1929 for the purpose of studying and breeding parasites for shipment to the United States.

These reasearches involved answers to such questions as (1) Could the spread of the beetle be prevented? (2) If not, could the grower economically control it with insecticides? (3) What would be the effect of the introduction of parasites? (4) What crop is it capable of destroying? (5) What would be the natural barriers to its spread over the entire area east of the Rocky Mountains?

BIOLOGY

Food plants.—The uncertainty as to the range of food plants of the bean beetle was a very disturbing factor when the insect was first found in the East. It was known that this pest was very destructive to the garden type of beans in the Southwest, but it was not estab-

lished whether the insect infested soybeans, cowpeas, and other legumes that were so important to the agriculture of the East. Studies on host plants soon revealed that its favorite foods were the common varieties of garden bean, tepary beans, and limas, which are grouped under the species *Phaseolus vulgaris* and *P. lunatus*. This food preference distinguished the insect as a pest of the home garden, and its fondness for and ability to thrive particularly on the "corn field," or pole bean, eliminated this important source of food to the home garden of the South during years when the insect was most abundant.

It can live and develop on certain other food plants. Next to beans, it prefers beggarweed or beggartick, a plant of the genus *Meibomia*. Its next choice is the hyacinth bean, followed in order by the cowpea and soybean. It may also feed to a limited extent on the adsuki bean, kudzu, and some clovers. In the early part of the season the insect does not, and apparently cannot, live on some of these latter-named plants, especially cowpeas and soybeans, whereas later in the season it seems to thrive on them. It has been only in comparatively rare instances that cowpeas and soybeans have been injured in the field, and in these cases it was observed that the beetles developed in large numbers on adjacent garden beans and overflowed onto the soybeans and cowpeas after their favorite food had become exhausted. Under threat of starvation it may be forced to feed on many types of plants, such as okra, eggplant, and squash. However, attack on these garden plants is rare, and the bean beetle has proved to be primarily a pest of garden beans.

Life history.—The bean beetle resembles in form and color some of the native beneficial ladybirds, to which family of insects it belongs. In form it is rounded, about one-fourth inch long and one-fifth inch wide; each brown or copper-colored wing cover bears eight distinct black spots. The immature form, or larva, is orange-colored; when full grown, it is about one-third inch long and is covered with comparatively long, soft branched spines, which give it a fuzzy appearance. The insect overwinters in the adult stage and prefers for winter protection a mixture of oak leaves and pine needles, located on woody slopes. With the approach of cool weather they congregate in such locations, crawling to a depth of several inches among the cover, where they will not be subject to rapid fluctuations of moisture and temperature. In the southern States the beetles may be found active during the warm days of the winter and in some instances may seek locations different from those originally occupied with the approach of cold weather. A few may remain and successfully overwinter in the old bean fields, but the majority will be found in nearby woodlands.

The overwintering beetles appear in the field at about the time that the earliest beans show their first true leaves. After feeding for a

short time the females deposit yellow eggs in groups of from 40 to 60 on the underside of the bean leaves. One female has been known to deposit over 1,500 during one season, and the average is nearly 500 per female. The time required for the development of the insect from egg to adult varies with the climate. The eggs may hatch in from 5 to 14 days, the larva requiring 15 days to 3 weeks to complete its development. In the pupal stage the insect may remain for a week or 10 days. There is no clear-cut line between generations and all stages of the pests may be found in the same field at the same time during the summer season. In the South there may be from two to four generations; in Ohio one or two generations may develop during the season. The beetles which have overwintered usually live until early summer.

The adult beetles are sluggish as compared with many of the insects encountered in a bean field. They crawl rather slowly and are not easily disturbed. At certain times of the year, however, many of the beetles take wing and in some cases fly high into the air and soon disappear from sight. In August the beetles become particularly restless and at this time the greatest dispersion takes place. Flight experiments conducted with a large number of marked beetles have shown that the insect will travel as far as 5 miles in 2 days and that movements of 3½ miles in the same length of time are not unusual. Considering the facts that over a period of 20 years only a few isolated infestations of the beetle have been found in the East and that the general movement has been in a northeasterly direction from the original infestation, the indications are that the spread has resulted from flight, probably aided by wind currents.

Nature of injury.—The injury caused by the adult and larva of the bean beetle to the foliage of the bean plant differs from that caused by any other insect that utilizes the bean as food. The adult feeds, as does the immature form, on the lower surface of the leaves, eating ragged areas in the leaf, but often cutting through to the upper surface, giving the foliage a lacelike appearance. The larva, on the other hand, feeds entirely on the under surface of the leaves and does not cut through the upper epidermis. Dr. Neale F. Howard describes the feeding of the beetle larva as follows: The mandibles are used alternately in scraping the tissue from the leaf between the veins. At intervals the mandibles meet and compress this loosened tissue, which remains on the leaf as small "windrows" or strips. As the plant tissue is compressed the larva apparently ingests the sap or plant juices and discards the more solid portion. When an infestation is heavy, the plant is practically destroyed and has the appearance of having been scorched by fire.

Natural enemies.—Apparently none of the insect parasites and predators of the bean beetle followed it from its original home into

the United States, as the parasites and predaceous insects occurring in the United States are of little value in keeping this insect in check. In 1921 H. F. Wickham collected near Mexico City, Mexico, a dipterous parasite of the bean beetle. In 1922 E. G. Smith, engaged by the Federal Bureau of Entomology, found a tachinid parasite of the larval stages of the bean beetle abundant at Mexico City and shipments were made of several hundred parasitized bean beetle larvae to Birmingham, Ala. This parasite was recognized as new and described by J. M. Aldrich as *Paradexodes epilachnae* in 1923. The parasite did not survive the winter in the Birmingham, Ala., area, nor become established after liberation in the field. It was thought that a more intensive study of the parasite and its host in Mexico might yield information which would insure its successful introduction in the United States, and in 1929 B. J. Landis was detailed to make such a study at Mexico City. Between July 1929 and October 1930, 60,000 puparia were shipped from Mexico City to Columbus, Ohio, and a serious attempt to colonize the parasites in the areas of the United States infested with the bean beetle was begun in 1930. Attempts to store larvae, adults, and puparia of the parasite through the winter months at Columbus, Ohio, were not successful, and a breeding stock was maintained from August 1930 to September 1935 by breeding the flies in the laboratory. Of the 145,500 adult parasites bred at Columbus, 82,000 were released in 19 States, including States from Alabama to New York in the East and Texas and New Mexico in the Southwest. The numbers of flies released in separate colonies ranged from 100 to 4,000 individuals and many of these colonies were restocked for several consecutive years. In most cases the parasites were found to have become established during the current season. However, in no instance has this parasite been definitely collected from colonies released the previous season, and consequently it must be concluded that the attempts to introduce this parasite were not successful. Many workers and observers have contributed information to our knowledge of the large array of parasites and predators found attacking the bean beetle in this country, but in the aggregate these natural enemies are of no great importance. This list includes, beside insect parasites and predators, bacteria and fungi, as well as a few birds and mammals.

Climatic factors.—The general climatic conditions of the eastern States have permitted the spread of the beetle over practically the whole region east of the Mississippi River. On the other hand, observations and studies have shown that there are certain areas within this region where the insect has been in general a more consistent pest than elsewhere. Roughly, this area may be designated in the Appalachian Range from the southern part of Ohio southward to

central Alabama. In the coastal area of the Carolinas, Georgia, Maryland, and Virginia, its occurrence in damaging numbers has been sporadic. Judging from the reports on outbreaks south of central Georgia and Atlanta the infestations in this area have been localized. The bean-growing areas of Michigan and southwestern New York have not been seriously affected by the insect, and the two infestations discovered in 1933 and 1935 in Minnesota and Iowa, respectively, apparently have not become of any importance to the bean crop. Studies have shown that during the hibernation period the lack of proper coverage to protect the beetle from rapid changes in temperature and moisture increases winter mortality and during the active season high temperatures, accompanied by drought conditions, will rapidly reduce populations of the insect and it is probably these latter factors that have been largely responsible for the variation in the seasonal abundance of the bean beetle in many sections. Winter mortality, although undoubtedly an important factor in the survival of the insect in any given area does not appear to be of paramount importance in relation to the seasonal abundance of the insect. Spring conditions following a high survival of the pest during the winter may result in low populations of the first generation of the beetles. Yet on the other hand, spring conditions following high winter mortality may promote a rapid development of the first generation of the beetles. Considering these factors then, it is hazardous to venture a prediction as to bean beetle conditions, based upon winter survival.

CONTROL

Quarantine.—In the early days of the infestation the entomologists' knowledge of the insect's ability to spread under its own power was limited, and it was first thought that a rigid quarantine of the infested area would prevent the insect's spread or at least retard it. Consequently, a Federal quarantine was imposed on May 1, 1921. It was soon learned, however, that because of the insect's ability to make strong sustained flights and its inherent urge to move, even in the presence of an adequate supply of favorable food, regulations on the movements of farm produce and other materials would not prevent its spread. Upon recommendations of J. E. Graf, who was in general field charge of the work for the Government, the quarantine was lifted 2 months later, July 23, 1921, and the money appropriated for its enforcement was returned to the United States Treasury.

Insecticidal studies.—At the outset the problem of control appeared to be one in which insecticides would play an important part, the insect being a gross feeder and developing on the exterior of the plant. It appeared to be simply a problem of determining which

of the insecticides available was best suited. A large number of insecticides were tested in field plots of garden beans near Birmingham, Ala. From these first tests the better known arsenicals such as lead arsenate and calcium arsenate were apparently satisfactory. However, after a number of field experiments had been performed with lead arsenate, it was noticed that bean plants treated with this material were sometimes stunted and were a darker green than normal. In one instance such severe injury followed its use by a grower that a complete loss of crop resulted. This was an unlooked-for development as lead arsenate had long been considered a standard stomach poison for insects and one which could be tolerated by most plants and had been used in the West to control the bean beetle. Zinc arsenite had also been used for the control of the beetle in the West, but its use caused injury to the bean crop in the South. Apparently the atmospheric conditions in the South rendered the foliage of the bean plant susceptible to the action of these arsenicals. Paris green, while toxic to the bean beetle, was very injurious to the plant foliage.

The work with calcium arsenate is of particular interest because it demonstrated the variability in different types or brands of this chemical to bean foliage. Throughout the early tests with calcium arsenate it was found that one particular brand was toxic to the bean beetle and would not cause foliage injury when diluted with hydrated lime, and as a result such a mixture was recommended for bean-beetle control. Calcium arsenate, being cheap and readily available, was extensively used. However, with the spread of the bean bettle many different brands of this insecticide were used by the grower, and complaints were received of chemical injury to the bean crop. Studies indicated that some brands of calcium arsenate were not suitable, and an extensive investigation was begun of the effect of all available commercial brands of calcium arsenate on the beans grown in the field. It was soon determined that the brands varied greatly in their effect on the plant. It was also learned that when the material was applied during periods of high humidity, injury was more likely to follow than when the atmosphere was dry. Chemical analyses made by chemists who were cooperating in the work indicated that there was no appreciable difference in the chemical composition of the various samples.

It was discovered that a sample of calcium arsenate that normally seriously injured foliage, lost its injurious qualities when autoclaved—that is, placed under steam pressure. Further investigation also indicated that the heat treatment of calcium arsenate, while it reduced the toxicity to bean foliage, also reduced the toxicity to the insect. As a result of these investigations much research relating to the manufacture and composition of calcium arsenate

has been undertaken, and undoubtedly sufficient knowledge will eventually be gained to permit the manufacture of a better product than has heretofore been available.

In these early tests was included a little-known arsenical, namely, magnesium arsenate. This material had been developed by a commercial company a few years before and had received little consideration as an insecticide because preliminary tests showed it to be injurious to the foliage of peach and apple trees. Continued experiments with it produced no visible signs of injury to the bean plant and gave excellent control of the bean beetle.

Even in view of this experimental evidence the Federal investigators were reluctant to recommend magnesium arsenate to the bean grower because of the experience of others with this material on peach and apple trees. Consequently, no recommendations were made after the results of the first season's work. During the following year the results of the experimental work were substantiated, and the use of this material was suggested to a large commercial canner, who used it on his snap beans and bush lima beans with excellent success.

Following this work, magnesium arsenate was recommended as a control of the bean beetle by the Department of Agriculture. However, it was poisonous to man and, when applied to the green bean crop, would leave a harmful residue unless treatments were discontinued before the pods began to form or the beans were carefully washed in several changes of clear water before consumption. Furthermore, it was not readily obtainable, as it was of little value as an insecticide for other purposes; consequently, it was not carried in stock by dealers in general.

The inadequate distribution of magnesium arsenate, the variation between brands of calcium arsenate, and the arsenical residue problem intensified the search for better materials. During this interval fluorine compounds were being investigated and sodium fluosilicate was recommended by S. Marcovitch, of the Tennessee Experiment Station. This material, while toxic to the bean beetle, sometimes caused plant injury. Later cryolite was recommended by the same investigator. This material yielded good control of the bean beetle and did not cause plant injury. However, its physical properties were such that it was not very suitable for use as a dust.

In 1931 a dust prepared from the root of the plant *Derris elliptica*, which contained a substance known as rotenone and had long been known as a fish poison, was first used in the field. The early results were not promising because, as was learned later, the rotenone content was not quite high enough. Work with this root, together with cube and timbo, other rotenone-bearing substances, continued as these materials showed promise and, above all, if proved satisfactory as a

bean beetle insecticide, would reduce the hazard of undesirable residues on the beans. By 1933 sufficient data had been accumulated to warrant the recommendation of the use of finely ground roots of derris and cube in water for the control of the bean beetle. Continued investigation with these materials showed them to be the most effective and superior to all others developed for the control of the insect, and they can be used with equally good results in the spray and dust forms, which is a distinct advantage under many circumstances. Since the first important recommendation for the use of derris dust for the control of a leaf-feeding insect which was widely distributed and very numerous in certain areas of the country was made in the case of the bean beetle, the studies on the control of this insect may be credited with having contributed largely to the extended use of this relatively new and valuable insecticidal root as well as other plant roots containing rotenone, such as cube and timbo.

SUMMARY

The Mexican bean beetle, although known in the southwestern part of the United States for 75 years or more, was first discovered in the Southeast in Alabama in 1920. Its introduction into the East was probably through shipments of alfalfa hay from an infested region of the West. In the East the beetle spread rapidly by flying in a general northeasterly direction. By 1932 it was present in all States east of the Mississippi River, with the exception of Florida and Wisconsin, and to the north as far as southern Minnesota. During the next 8 years its spread was greatly retarded, infestations being found only a little farther north in Michigan, New York, and Maine, and in the South scattered infestations had been reported in the Gulf region from Florida to Louisiana.

The beetle's presence and spread in the East was viewed with great concern by those engaged in the production of beans, as the crop heretofore had been comparatively free of insect attack. Federal field research laboratories were established in several sections of the United States, and one was set up in Mexico, to study the habits of the beetle and methods for its control.

The beetle was found to be most destructive to garden beans, occasionally feeding on leguminous crops such as cowpeas and soybeans. Two broods of the pest may occur in the northern part of its range, whereas four will develop in the southern States. The beetle chooses for hibernation quarters accumulations of fallen leaves of deciduous trees and pine needles. It will, however, hibernate in the open fields in the South under crop remnants and dead weeds.

Severe damage to the bean crop occurred as the beetle increased its range. This damage was usually very severe during the season that

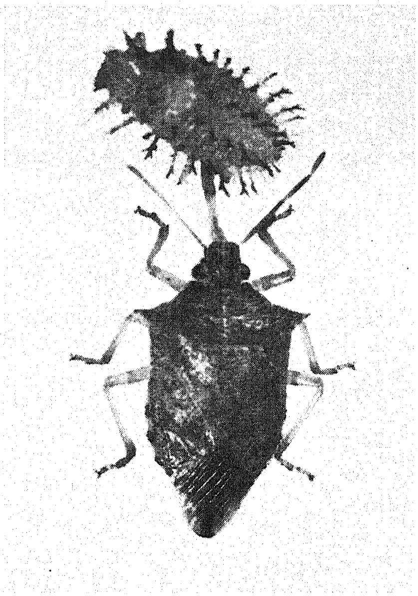
the insect was found in new territory. The home gardener suffered particularly from the depredations of the pest.

High temperatures accompanied by drought during the active season apparently constitute the most important natural factors in inhibiting the insect's development. Winter mortality, or survival of the beetles, is not an index to seasonal abundance, because of the influence of spring weather conditions on the development of the first generation.

A parasite introduced from Mexico was successfully reared in large numbers in the laboratory and liberated in 19 States, but as no recoveries were made in the field following these liberations it has been concluded that this attempt at the introduction of a foreign parasite was unsuccessful. A large number of other natural enemies have been reported, but these exert little, if any, influence on the beetle population.

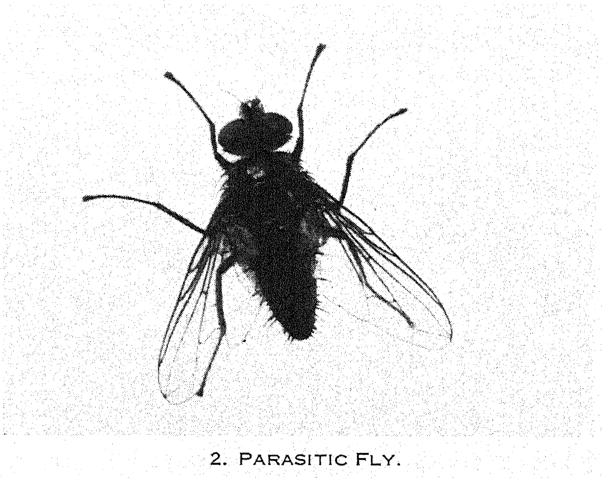
Magnesium arsenate was developed as a control for the pest, along with calcium arsenate, cryolite, and sodium fluosilicate. Finally, the rotenone-bearing roots, such as derris, cube, and timbo, were shown to be the most effective insecticides. These materials could be used effectively both in the form of a liquid spray and a powder or dust.

Although the insect remains an important pest of beans over the greater part of the Eastern area, its depredations can be checked by the proper application of the control measures now available.



1. A SOLDIER BUG ATTACKS THE LARVA OF THE BEAN BEETLE BY PIERCING ITS BODY WITH A SHARP BEAK AND SUCKING THE BODY CONTENTS.

Photograph by Howard.



2. PARASITIC FLY.

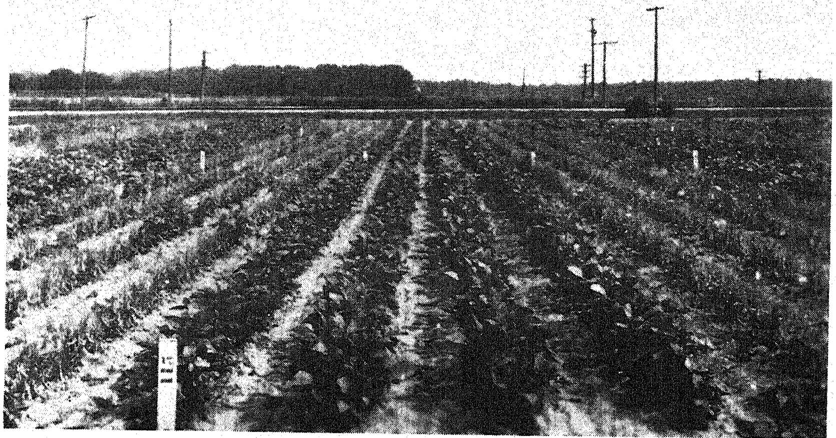
The adult parasite, *Paradexodes epilachnae,* deposits its eggs on the body of the bean beetle larva, the newly hatched maggot of the parasite enters the body of the bean beetle larva and feeds and grows with its host. However, the host dies as it nears maturity as the result of the parasite's feeding. Photograph by Howard.

1. BEETLES IN WINTER QUARTERS.

With the approach of cold weather the beetles congregate in sheltered locations. Protection afforded by accumulations of oak leaves and pine needles enables them to withstand the winters more successfully than other types of materials. Photograph by Howard.

2. BEANS INJURED BY LARVA OF BEAN BETTLE.

The whitish appearance of the bean foliage is due to the feeding of the bean beetle on the under surface of the leaves. Damage of this nature naturally results in loss of crop. Photograph by Howard.



1. EXPERIMENTAL PLOT OF BEANS.

The center rows of beans were protected with an insecticide. The rows to the sides have lost their foliage from bean beetle attack as they were not treated. Photograph by Brannon.

2. INJURED BEAN FIELD.

The bean plants in this field were left without leaves after being attacked by the bean beetle.

1. TRACTION DUSTER.

The use of dusters equipped with a special spoon-shaped nozzle arranged on the end of the outlet tube so that the dust is directed upward to the under sides of the leaves has proved an effective means of treating the bean crop with dust. Photograph by Howard.

2. TRACTION SPRAYER.

The use of sprayers with nozzles arranged in such a manner so as to cover the entire plant with liquid insecticides has proved more effective than dusters. Photograph by Howard.

HAND DUSTER, PLUNGER TYPE.

The home gardener will find this type of duster useful in treating small plants with a powder or dust. Photograph by Howard.

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PLANT-TISSUE CULTURES

By Robert L. Weintraub
Division of Radiation and Organisms, Smithsonian Institution

[With 3 plates]

The living plant may be likened to a great factory in which a large number of physical and chemical operations are proceeding simultaneously. In the plant, to an extent even greater than in the factory, each of these processes may be affected by any or all of the others and may, in turn, exert an influence upon them. All the living parts of the plant respire continuously, day and night, absorbing oxygen from the air, burning a portion of the living substance or stored material, and excreting carbon dioxide. From the soil the roots absorb water and minerals which are then moved into the aerial portions. In the light the green tissues manufacture carbohydrates which are supplied to all the rest of the plant and which are transformed into building materials such as cellulose and proteins and into storage reserves such as starch and fat. Many of these processes, furthermore, are markedly influenced by environmental factors such as temperature of the air and soil, humidity, and composition of the atmosphere, illumination, and supply of water and minerals. The particular set of environmental conditions which is most favorable for a given physiological function is not necessarily the best for any other process.

Such a bewildering intricacy renders very difficult the task of the plant physiologist who seeks to gain an understanding of the nature of the various life processes and the interrelationships that exist among them. If it were possible to separate mechanically the individual tissues and organs of the plant and to maintain them under known and controllable conditions while they continued their normal activities, an important advance toward an analysis of the problem would have been achieved. This was first clearly recognized by the German botanist Haberlandt, who wrote in 1902:

> So far as I know, there has been, up to the present, no well-planned attempt to cultivate the isolated vegetative cells of higher plants in suitable nutrients. Yet the results of such cultures should throw many interesting sidelights on the peculiarities and capacities of the cell as an elementary organism; they should bring into evidence the reciprocal relationships and many-sided influences to which the individual cells of a multicellular organism are subjected.

Incidentally, this statement by a botanist antedates by some years the first work with animal-tissue cultures, which in the hands of Carrel and others, has yielded such noteworthy results.

Any definition of just what constitutes a tissue culture must be arbitrary. For the present it may be convenient to adopt the definition formulted by White, who considers a plant-tissue culture to be "any preparation of one or more isolated, somatic plant cells which grows and functions normally, in vitro, without giving rise to an entire plant." This would exclude spore cultures, cultures of whole embroys, or other propagula. It should be realized, however, that this definition contains a joker, namely, the requirement of "normal" growth and function; to determine whether growth and function of a culture are indeed normal may at times be a task of almost insurmountable difficulty.

Although it was early realized that tissue cultures might furnish a very useful tool in the elucidation of many problems, it was not foreseen how laborious would be the fashioning and sharpening of the tool for use. This preliminary technical preparation, which has been attended by many difficulties, has been the objective of most of the work so far accomplished and it is only in the last few years that the ground work has been developed sufficiently for the application of the method to other problems.

It is of interest to review briefly some of the highlights of the work of the past four decades.

Although a considerable amount of work was done by Haberlandt and his students and by other investigators, the early results were not encouraging. The immediate impetus for recent work has come from the successful cultivation of excised roots, and the present account will be concerned principally with this phase.

By one of those coincidences that sometimes occur in experimental work two investigators, Kotte in Germany and Robbins in the United States, without knowledge of each other's work, published in 1922 the first reports on cultivation of excised root tips in nutrient media. Curiously enough, both investigated the roots of peas and corn. The general technique adopted in these experiments and in nearly all subsequent studies was to cut off the root tip of a seedling which had germinated under aseptic conditions, transfer it to the nutrient medium, allow it to grow for a week or two, again cut off the tip and transfer this to fresh media. This procedure was continued as long as growth ensued, the objective being to prepare an environment in which growth would proceed indefinitely. Such continued growth was not achieved by either Kotte or Robbins, and success was first attained a decade later by White with tomato roots. Using a liquid medium containing sugar, a number of inorganic ions, and a small amount of a water extract of yeast, White has been able to maintain

tomato roots in culture for more than 7 years. Since the roots were customarily subcultured at weekly intervals, this period represents approximately 350 transfers. Under the culture conditions employed, the excised roots elongate at a rate substantially equal to that of normal intact roots, averaging about 5 millimeters per day and producing one or two new branch roots daily. At this rate, if one started a culture with a single 10-millimeter-long root tip which at the end of one week was divided into seven pieces, each including a growing point capable of further development, and continued this procedure each week, maintaining all the subcultures so derived, there would be produced in 4 months a total length of root equal to the distance from the earth to the sun. In 7 years the length of roots produced would be a superastronomical figure: 265×10^{290} miles.[1] The dry matter contained in these roots would be equal to about 7×10^{263} times[2] the mass of the earth. This represents an extent of root system of which any tomato plant might well be proud.

The continuance of growth for such a long period of time proves that the development of the excised tomato root does not depend upon any growth substance or hormones which might have been supplied by the root tip from which the culture was originally started. Since each of the branch roots produced is capable of growth at a rate equal to that of the original explant it must be assumed that these branches have received a portion of any hypothecated essential growth factor initially present. A simple calculation shows, however, that even if the original root tip consisted exclusively of such growth hormone molecules, by the end of 5 months of weekly subculturing there would be more subcultures than the original number of molecules.

The excised tomato root was thus shown to be capable of completely satisfying its requirements from the materials furnished in the nutrient solution. It then became of interest to determine just what the minimum requirements might be. It should be realized that the solution of this problem is exceedingly laborious. In addition to the large number of combinations of nutrient media which must be studied when a dozen or more components are involved, there exists the possibility that the value of a given constituent may vary according to the presence or absence of other nutrients. A final answer must be approached by a series of successive approximations and generalized conclusions should be reached with considerable caution. The complexity of the situation has given rise to serious disagreement among various investigators. With better understanding of the numerous factors which are concerned these differences will doubtless be resolved.

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[1] $265 \times 10^{290} = 265$ followed by 290 ciphers.

[2] $7 \times 10^{263} = 7$ followed by 263 ciphers.

A particularly perplexing question has been raised by the report of one group of workers that the carbohydrate requirements of excised tomato roots may be satisfactorily met by either glucose or sucrose, while in another laboratory glucose has been found entirely unsuited for the growth of the same species of roots.

As has been mentioned, a satisfactory nutrient medium consisted of known substances with the exception of yeast extract which, although it comprised only one-hundredth of 1 percent of the total solution, was nevertheless indispensable. Roots placed in nutrient solution lacking the yeast extract ceased growth within a few days. Since yeast extract contains a great variety of materials the first problem was the identification of the substance or substances responsible.

In 1937, within the course of a few months, workers in three laboratories announced that the yeast extract could be partially or entirely replaced by vitamin B_1, a substance of which the composition was known and which can be prepared synthetically. Subsequent investigation has indicated that vitamin B_1, or thiamin, alone is not an adequate substitute for the yeast extract and that maximal growth can be obtained only when additional materials are supplied. Since there is not, as yet, complete agreement as to the nature of these additional factors a tabulation of the findings of the laboratories which have contributed the bulk of our information on the nutrition of excised roots is instructive.

Bonner	Robbins	White
February 1937: Vitamin B_1 completely replaces and is superior to yeast extract for pea roots.	March 1937: Yeast extract may be partially replaced by vitamin B_1 for tomato roots. Growth is improved by the addition of supplementary mineral elements but is still less than in yeast extract.	July 1937: Two fractions, active in the growth of tomato roots, can be separated from yeast. One of these can be replaced by a mixture of 9 amino acids; the other fraction can be replaced by vitamin B_1 provided that a mixture of 12 supplementary inorganic salts is also supplied. Yeast extract is not equaled, however, even by the vitamin B_1 plus the amino acids plus the accessory salts.
September 1937: Vitamin B_1 alone only partially replaces yeast extract for pea roots. A mixture of 16 amino acids is capable of substituting for that portion of the yeast extract activity which is not due to vitamin B_1. The mixture of vitamin B_1 plus amino acids is equal or superior to yeast extract.	July 1937: The entire thiamin molecule need not be furnished. Equal or better growth of tomato roots is obtained by supplying the thiazole portion of the vitamin B_1 molecule.	April 1938: Reduction of the number of accessory inorganic compounds to four (supplying manganese, boron, zinc, and iodine) in a medium containing thiamin and the 9 amino acids gives growth of tomato roots nearly equal to that in yeast extract.
December 1938: Thiamin plus amino acids is not a complete substitute for yeast extract. Nicotinic acid is also an essential growth factor for pea roots. The amino acids are not essential.	January 1939: Addition of nicotinic acid or an amino acid mixture is of no benefit to tomato roots supplied with thiamin. Addition of vitamin B_6 increases the growth several-fold.	July 1939: No single one of the 9 amino acids is indispensable for tomato roots and the entire mixture may be replaced by glycine which is structurally the most simple of the amino acids. For sunflower roots the thiamin plus glycine medium is far superior to yeast extract whereas clover roots grow very poorly in it.
October 1939: Pea roots grow better when supplied with thiamin plus nicotinic acid than in yeast extract. Radish roots also require vitamin B_1 and nicotinic acid. Flax roots require viatmin B_1 but not nicotinic acid. Growth of tomato roots continues indefinitely if the yeast extract is replaced by vitamin B_1 plus vitamin B_6 but the rate is increased if nicotinic acid also is furnished.	March 1939: Growth of tomato roots supplied with thiamin plus vitamin B_6 is several times as great as in yeast extract. In the presence of vitamin B_6 the appearance of the roots is abnormal. Evidence of the occurrence, in various sugars, of an additional, as yet unidentified, growth factor has been obtained.	

It is becoming increasingly evident that the roots of various species of plants may differ sharply in their nutrient requirements and that, in the present fragmentary state of our understanding, generalizations are unjustified. It is of interest that, while some success has been had with roots of about two dozen dicotyledonous species, not a single monocotyledonous root has been grown continuously despite numerous attempts.

Lest a misleading impression be created it should be emphasized that the root cultures so far discussed are in no sense root systems but merely rootlets. As they age, these excised root cultures do not exhibit secondary thickening, as do normal roots, but remain indefinitely in a juvenile condition. Typical cultures of this kind are illustrated in figures 1 and 2.

In unpublished work of the author a somewhat different objective has been considered. It has been attempted to produce an excised root system resembling that normally developed by the intact plant

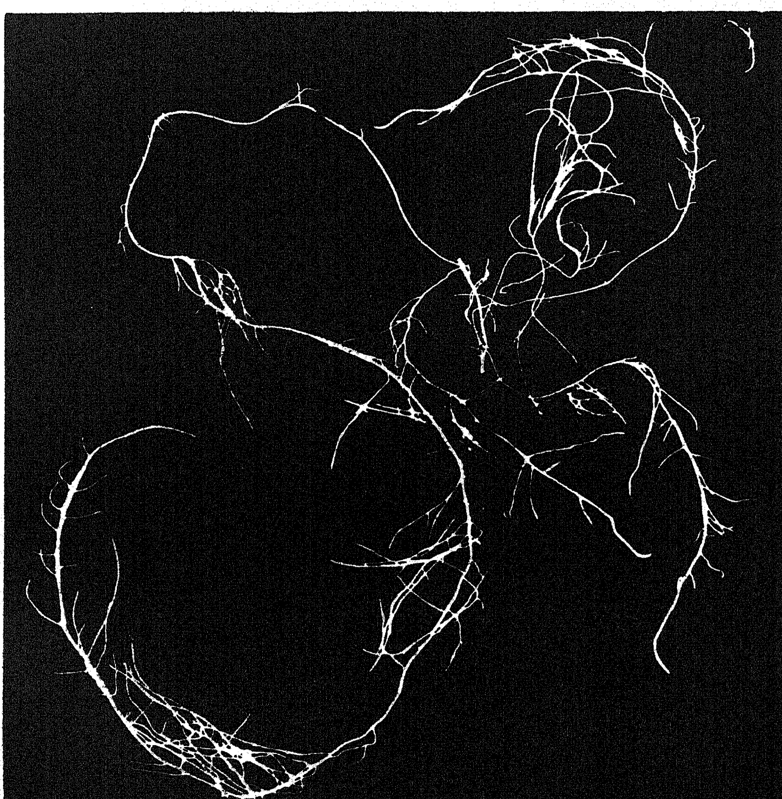

FIGURE 1.—Excised root of tomato. The fragment with which the culture was started can be distinguished near the center of the photograph. Courtesy of Dr. W. J. Robbins (Bot. Gaz., June 1938).

rather than to subculture the root tips indefinitely. Partial success has been attained with the root of the white moonflower (*Calonyction aculeatum*). This species seems to have much simpler nutrient requirements than any of those mentioned above. A root system, developed from an excised root tip, which exhibits more or less normal secondary thickening is shown in figure 3. This root was grown in a nutrient solution containing only inorganic salts and sugar without any other organic material. It has been proved by analysis that in such a medium the moonflower root is able to elaborate its organic nitrogenous constituents, such as amino acids and proteins, from supplied inorganic nitrogen.

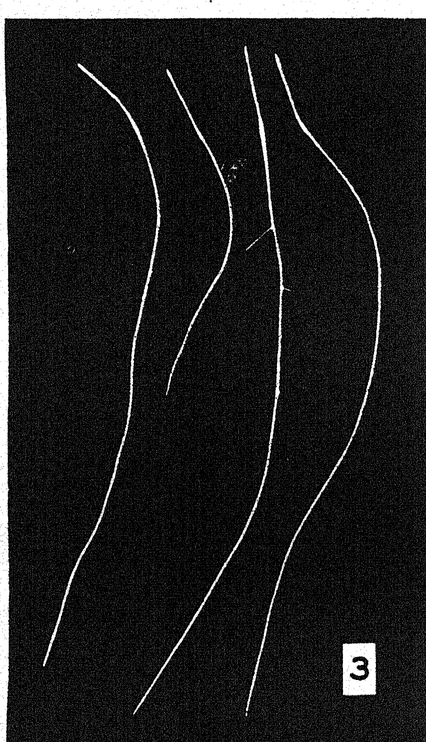

FIGURE 2.—Excised pea roots after continued subculturing. This species branches very sparingly in culture. Courtesy of Dr. F. T. Addicott (Amer. Journ. Bot., October 1939).

We may now examine briefly some of the problems of plant physiology toward the solution of which the study of excised root cultures has been directed.

In the first place the nutrient studies themselves are beginning to throw some light on the chemical transformations that occur in the plant. The three growth factors, vitamin B_1, nicotinic acid, and vitamin B_6, which have been claimed as essential, all belong to the large vitamin B complex. So far as is known at present these

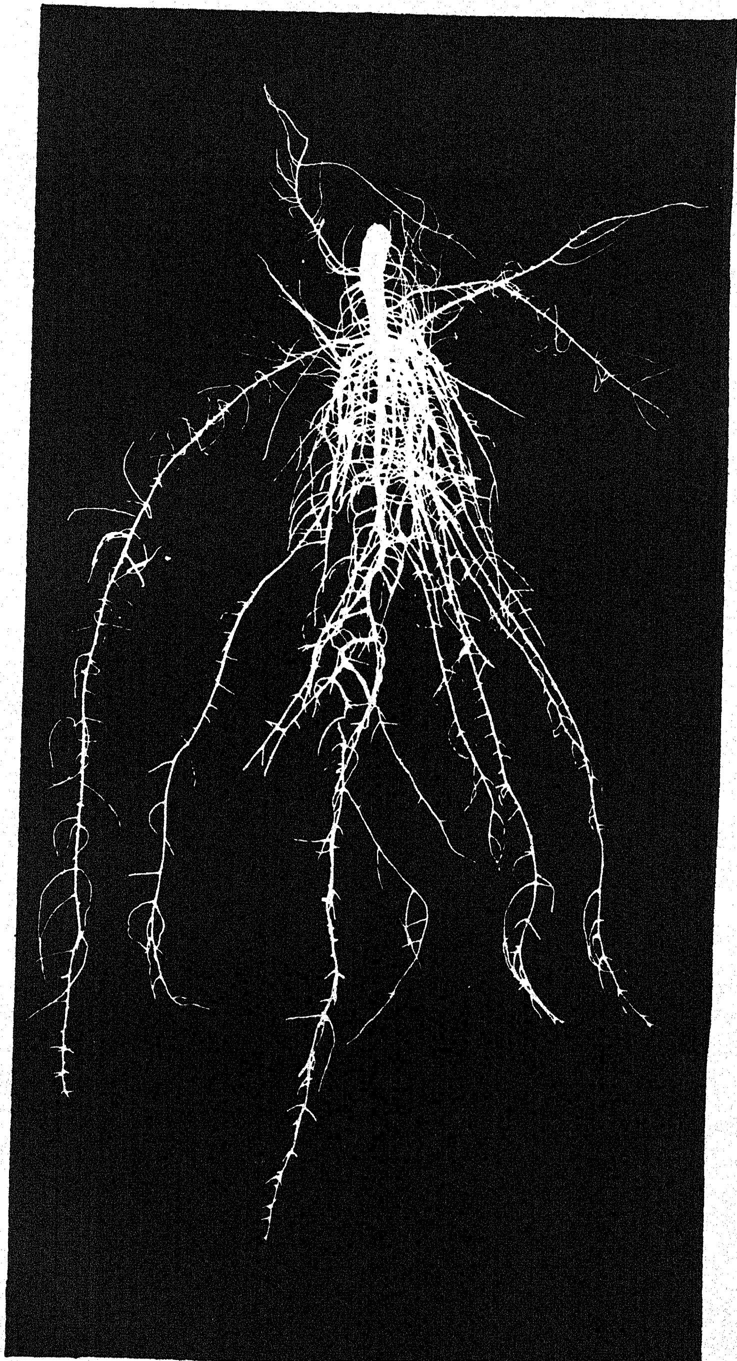

FIGURE 3.—Excised root of white moonflower. Note secondary thickening of the older portion of the primary root.

all appear to be involved in the utilization of carbohydrates in the respiration of the living cell. It would seem likely therefore, that there is considerable similarity among the mechanisms by which this fundamental vital process is performed in plants and in animals. It is possible, of course, that those roots which do not appear to require an external supply of a given growth factor are able to synthesize the substance from simpler nutrients which are supplied.

It is very interesting that in the case of thiamin, a mixture of the two portions of the molecule[3] is just as effective as the complete thiamin molecule itself. The root appears capable of synthesizing the vitamin from these building blocks. Furthermore, the vitamin B_1 requirement of the tomato root can be met by supplying only the thiazole portion; this species seems to have the capacity to manufacture the pyrimidine portion necessary to complete the molecule. The pea root, on the other hand, is unable to do this.

Excised roots have been used also to study the synthesis of vita min C, or ascorbic acid, in the root. The production of vitamin C in intact plants appears to be intimately connected with the chloroplasts and yet the vitamin is of very widespread occurrence in the roots and other nongreen parts of such plants in which chloroplasts are lacking. The question arises whether it is actually manufactured in the roots or is transported to them from the shoot. Now, excised moonflower roots develop chlorophyll if cultured in light but not if grown in darkness. Although they make good growth in the dark, their content of vitamin C does not increase. In light, however, the ascorbic acid content increases 400 to 1,000 percent. From this finding, it seems probable that the colorless roots of intact plants do not synthesize vitamin C but receive their supply from the green tops. It should be mentioned that there is, as yet, no direct evidence that this vitamin plays a role in the vital economy of the root.

In recent years there has accumulated a large body of evidence which indicates that the growth and behavior of various organs of the plant are regulated by growth-promoting substances or hormones. The problem of the relationship of growth substance to root growth shows a number of similarities to the vitamin C problem. Growth substance seems to be present in all roots so far investigated but, curiously enough, concentrations of growth substance, or auxin, which stimulate the growth of shoots are inhibitory to roots. Root elongation may possibly be somewhat enhanced, however, by extremely dilute growth substance solutions (1 part in 10 billions to 1 part in 100 billions). One would like to know whether the growth substance is produced in normal intact roots or whether

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[3] The vitamin B_1, or thiamin, molecule can be split into two fractions, one consisting of a thiazole, the other of a pyrimidine grouping.

it is supplied to them from the shoots. A number of growth-substance studies with excised roots have been carried out but, unfortunately, the results have been conflicting so that a definite answer cannot yet be given. Since it is established that the excised root can grow indefinitely without any external supply of growth substance it must be concluded that if auxins are indeed necessary for root growth they are manufactured by the root itself. In this connection it is of interest that the excised root does not lose its capacity for responding to the force of gravity, a property generally assumed to be related to the action of growth hormones. The geotropic response of excised corn roots cultured in a solid agar medium is shown in plate 1. The position of the tubes in plate 1, left, was altered at intervals so as to change the direction of the gravitational stimulus; the tubes shown in plate 1, right, were maintained in a vertical position throughout.

One of the first uses to which excised root cultures were put was the maintenance of stocks of plant-disease viruses. The roots of tomato were used for the cultivation of the viruses of aucuba mosaic and of tobacco mosaic. Such cultures have the advantage of being free from accidental contamination with other viruses, of requiring comparatively little space, and of permitting close control of environmental and nutritional conditions. It is interesting that the infected roots did not exhibit any symptoms of disease although the virus multiplied actively in them.

Work along somewhat similar lines was undertaken several years ago by Lewis and McCoy in an attempt to induce nodulation by root-nodule bacteria on excised legume roots. Although some nodules were produced by Rhizobium on excised roots of the black wax bean, the results were not very satisfactory, owing possibly to unfavorable culture conditions. The use of the tissue-culture technique would appear to be of great value for the study of many problems related to the physiology of nitrogen fixation by root-nodule bacteria since the nutritional and environmental conditions can be so easily and so precisely manipulated. In view of the great strides in technique made since the above-mentioned experiments were performed, a renewed attack appears to offer considerable promise.

Of the various applications to which excised roots have been put perhaps the most striking is the study of root pressure.[4] In these experiments the basal end of a single excised tomato root was inserted into a capillary manometer and the root with manometer was then returned to a flask of nutrient solution (pl. 2). In this way

[4] A report of this work, for which the $1,000 prize of the American Association for the Advancement of Science was awarded to Dr. Philip White in 1937, appeared in the Annual Report of the Smithsonian Institution for 1938, pp. 489–497.

the rate and amount of excretion of liquid from the base of the root can be measured. It was found in the first experiment that the rate of secretion into the manometer was rather large and, surprisingly, that it was the same whether water or mercury was used in the manometer. Figure 4 shows the results of an experiment which was continued for a period of 12 days. It will be seen that the secretion continued undiminished even against a pressure of at least two atmospheres. It was next attempted to determine how great a pressure could be developed by the roots. For this purpose compressed air was applied to the manometer. (See fig. 5.) Since

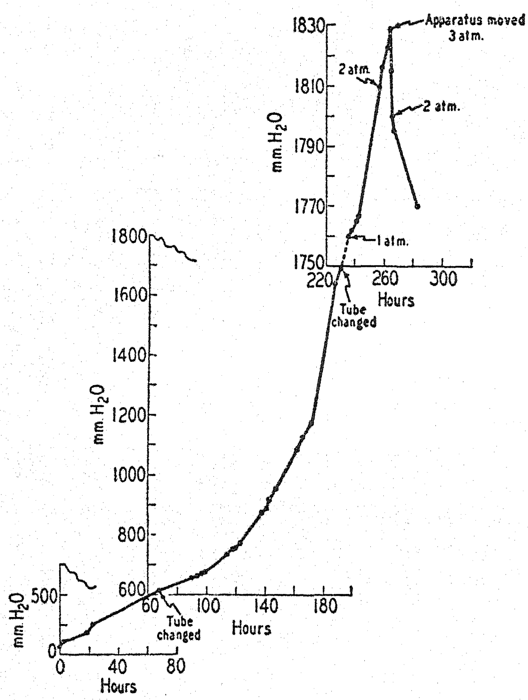


FIGURE 4.—Curve showing the effect of imposing pressures up to 3 atmospheres against the secretion pressure developed by a single excised tomato root. Courtesy of Dr. P. R. White (Amer. Journ. Bot., March 1938).

the pressure gage employed could not be used at pressures above 100 pounds per square inch, the experiment had to be terminated after six atmospheres had been applied; even this pressure did not bring about any observable retardation of the liquid excretion. It must be concluded from this finding that even six atmospheres is so small in comparison with the secretion pressure actually developed by the roots as to be quite insignificant. But even six atmospheres is sufficient to sustain a column of water 200 feet high, far in excess of the requirement of any ordinary tomato plant. From

this work it would seem that we have another possible answer to the old problem of what makes the sap rise in tall trees.

One would like to know a great deal more about this phenomenon: the nature of the force responsible for the secretion, for example, and the composition of the secreted liquid; but these must all await future research. Attention should be called to the very interesting rhythmic character of the secretion curve. The rate of secretion consistently exhibits a clear diurnal rhythm, being high during the day and falling off nearly or quite to zero at night. Since the roots were cultured in natural daylight it is interesting to speculate that the rhythm is related to illumination, although the tomato roots do not contain chlorophyll and their growth is unaffected by light.

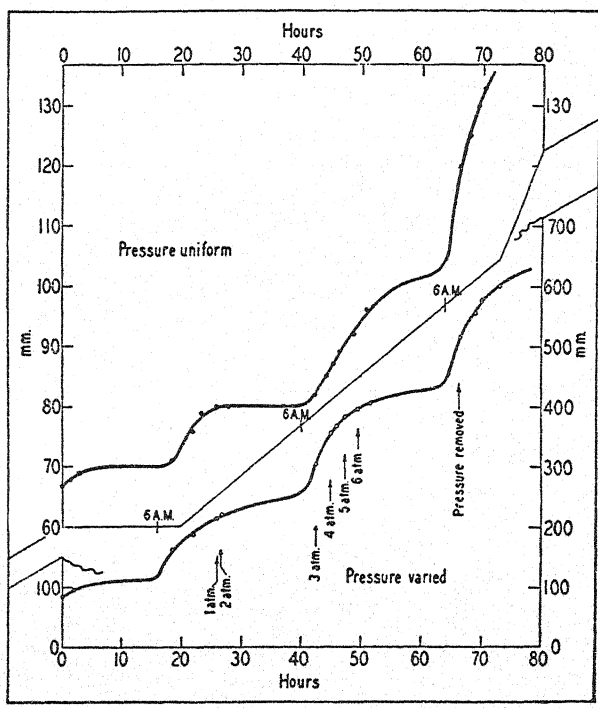


FIGURE 5.—Curves showing the rates of secretion of two similar excised tomato roots, one at uniform (atmospheric) pressure, the other against imposed pressures up to 90 pounds per square inch. Note the diurnal rhythm exhibited by the curves. Courtesy of Dr. P. R. White (Amer. Journ. Bot., March 1938).

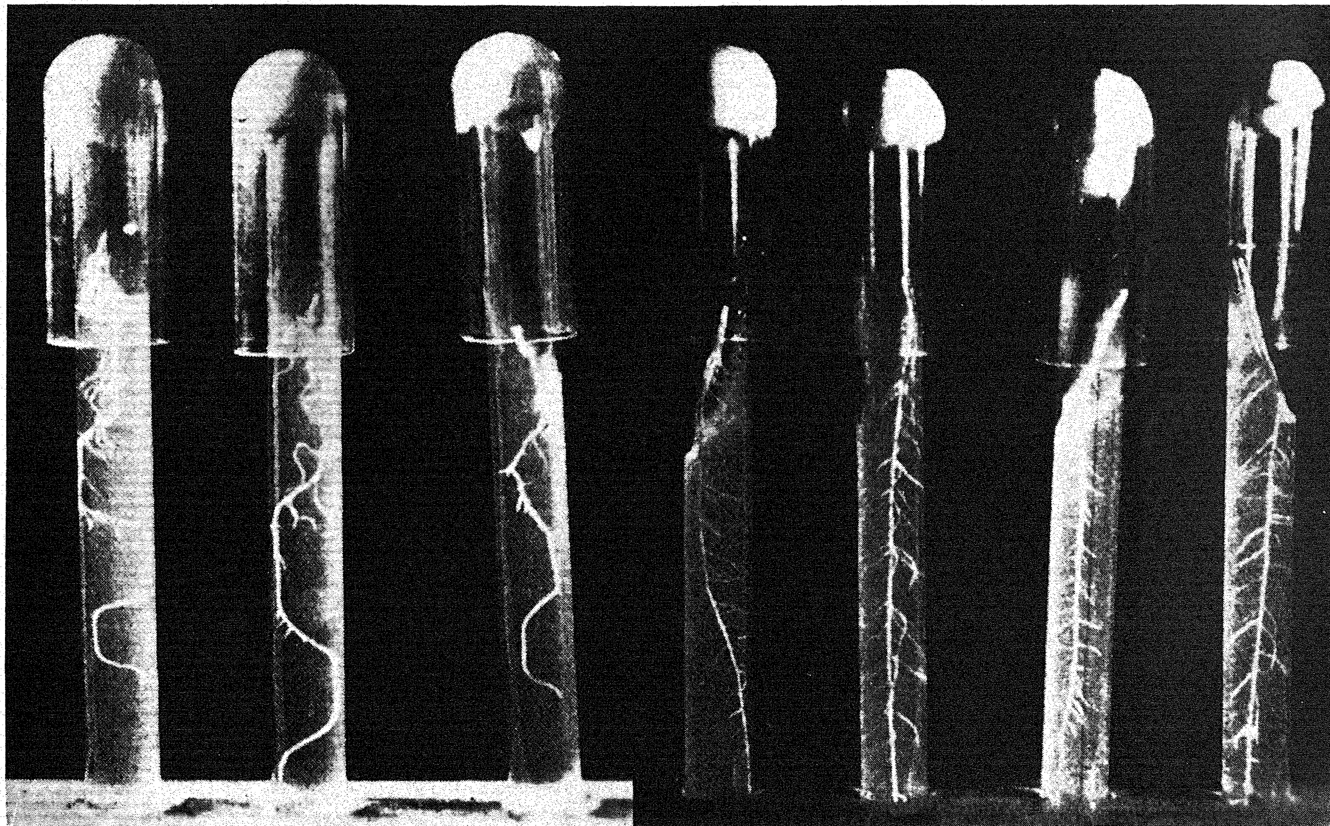
The present discussion so far has been confined to roots. In a strict sense these root cultures are not tissue cultures at all but rather they are organ cultures. It has been mentioned above that a great deal of the earlier research in the field of plant-tissue cultivation was concerned with attempts to culture isolated cells and fragments of other tissues such as parenchyma, epidermis, and various types of

hairs. In general, these experiments may be considered as unsuccessful and it was not until a few years ago that the French botanist Gautheret succeeded in obtaining actively growing cultures of cambial tissue of various plants. These may be regarded as possibly the first examples of true plant-tissue cultures.

Without attempting any further review of earlier studies reference will be made to only one recent research on plant-tissue cultures other than roots. It has been found by White that small fragments of tissue excised from a plant callus may be cultured on a semisolid agar medium. Such cultures are illustrated in plate 3, figures 1 and 2. Except for the production of an occasional scalariform cell no evidence of cellular differentiation or of polarity is exhibited by callus cultures on such a medium. If, however, a culture that has been maintained in an undifferentiated state during 10, 25, or 40 weekly transfers is then placed in a liquid nutrient (the same solution minus the agar), a marked transformation occurs within a few weeks (pl. 3, fig. 3). Growing points differentiate at the surface of the cell mass and develop into stems and leaves in exactly the same manner as in similar calluses when attached to the plant.

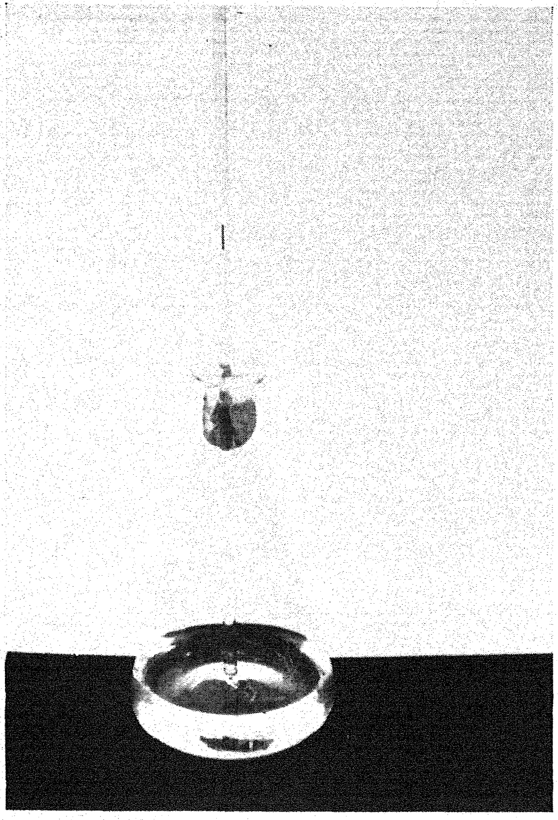
The simple expedient of immersing the tissue mass under about 8 millimeters of liquid instead of exposing it on the surface of the medium has thus resulted in a profound alteration of the developmental behavior. It has not as yet been determined just what factor is responsible for this effect; the most obvious difference between the two media is the restricted oxygen supply in the liquid culture. The significant point in this work is that the capacity for differentiation of the cells has not been lost but can be suppressed or evoked by simple technical manipulation. There is hereby opened up another avenue for the investigation of the developmental potentialities of the cell.

In this short review it has been attempted to call attention to the outstanding problems and achievements of the study of plant-tissue cultures. With the establishment of a secure experimental foundation one may confidently venture to predict a rapid and fruitful development of this phase of botanical research.



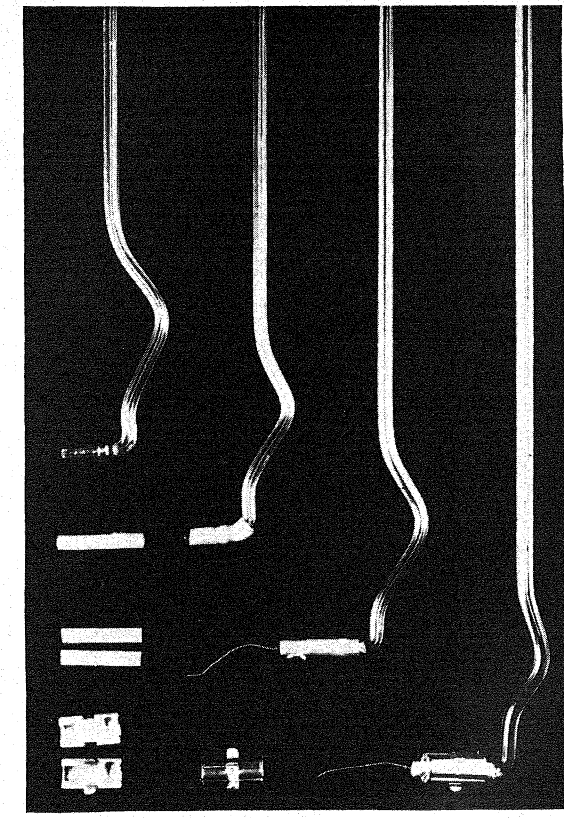
EXCISED CORN ROOTS CULTURED IN A SOLID AGAR MEDIUM, SHOWING THE GEOTROPIC RESPONSE.

The position of the three tubes at the left was altered at intervals; the four tubes at the right were maintained in a vertical position. From Fiedler (Zeitschr. Bot., vol. 30, 1936).



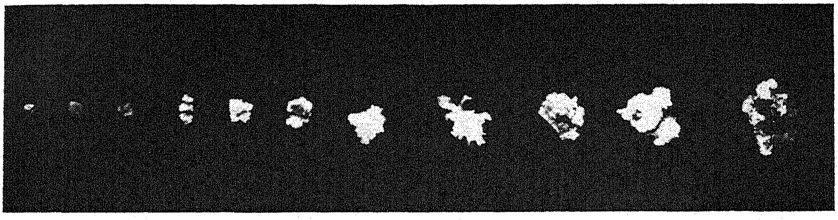
1. EXCISED TOMATO ROOT ATTACHED TO MANOMETER.

Courtesy of Dr. P. R. White (Amer. Journ. Bot., March 1938).



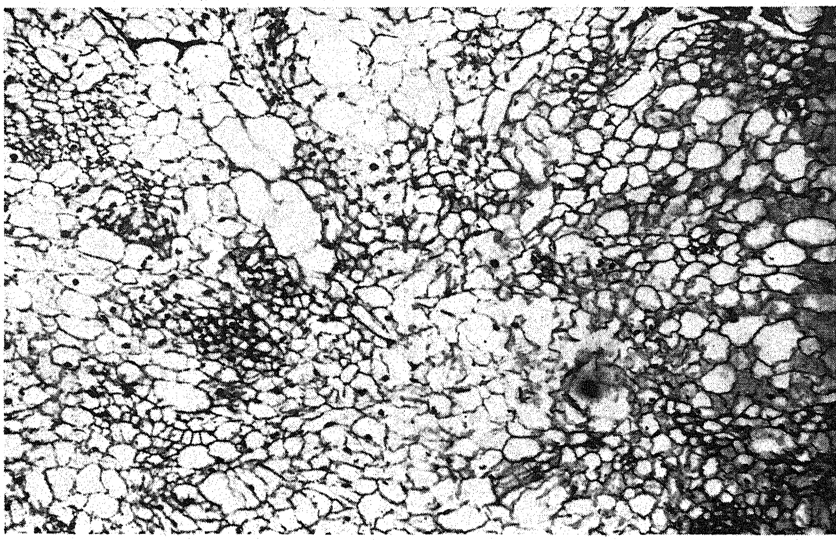
2. APPARATUS, CONSISTING OF GLASS MANOMETER, RUBBER CONNECTING TUBE, AND METAL CLAMP, USED IN MEASURING SECRETION FORCE OF EXCISED ROOT.

Courtesy of Dr. P. R. White (Amer. Journ. Bot., March 1938).



1. CULTURES OF TOBACCO CALLUS CULTIVATED IN VITRO FROM 0 (EXTREME LEFT) TO 10 WEEKS (EXTREME RIGHT).

Courtesy of Dr. P. R. White (Amer. Journ. Bot., February 1939).



2. TRANSVERSE SECTION THROUGH CENTRAL PART OF AN 8-WEEKS-OLD CALLUS CULTURE.

Courtesy of Dr. P. R. White (Amer. Journ. Bot., February 1939).

3. CALLUS CULTURES.

Left, callus cultured for 20 weeks on a semisolid agar medium; right, a similar culture grown for 10 weeks on the agar medium, then transferred for 10 weeks to a liquid medium containing the same nutrient materials but without the agar. Courtesy of Dr. P. R. White (Bull. Torrey Bot. Club, November 1939).

THE BOTANY AND HISTORY OF ZIZANIA AQUATICA L. ("WILD RICE")[1]

By Charles E. Chambliss
Bureau of Plant Industry, United States Department of Agriculture

[With 9 plates]

For this evening I have assembled some of my field notes on *Zizania aquatica*, together with some historical data on the species, which I trust will meet the requirements of this occasion. And this is my story.

Life was easy for Wenibozho.[2] His indulgent grandmother, with whom he lived, demanded no work of him, and in consequence he passed through his early boyhood days without exhibiting any particular interest in those things that must be learned and thoroughly understood by people who depend largely upon self for the necessaries of life.

At last, the grandmother awoke to the fact that her grandson lacked the initiative so essential to meet the requirements of their race, and convinced that her solicitous care was responsible, the aging woman urged the indifferent youth to prepare himself with a training that would fit him to endure such hardships as hunger, thirst, and cold. She told him that experiences of this kind would make him resourceful and teach him how to care for himself and those who might be dependent upon him. Probably somewhat irked by these plain words, Wenibozho later said goodbye to his grandmother, who for many years had provided him with food and shelter.

Equipped with only a bow and some arrows, he started on a long journey through the forest. For meat, he had to depend upon the flesh of small animals. Not because there was a scarcity of animals, for they abounded in the woods, but because of his unskilled use of the bow, his kills were few. Therefore, he had to subsist on seeds, roots, and tubers. Without knowing the plants that could furnish nourishing food, he naturally made mistakes.

One day when thoroughly exhausted from want of food he heard a voice saying, "Sometimes they eat us." He heard this voice several

[1] Address of the retiring president of the Washington Academy of Sciences, delivered on January 18, 1940. Reprinted by permission from the Journal of the Academy, vol. 30, No. 5, May 15, 1940.

[2] Gilmore, Melvin R., Prairie smoke, pp. 195–198, 1929.

times and finally asked, "To whom are you talking?" A small bush replied that it had spoken. As no part of the bush above the ground seemed edible, Wenibozho thought that the roots might be good to eat. He uncovered the roots, tasted them, and liked the flavor of them very much. Being hungry, he ate many of them and suffered from overeating. For several days he was unable to travel, and when he attempted to do so he found himself as hungry as before and quite weak. As he passed along seeking food, many plants spoke to him. Wenibozho gave no heed to their entreaties until he was attracted by the beauty of a graceful grass growing in a small lake basking in the sunshine of the open woodland. Some of these plants beckoned to him and said, "Sometimes they eat us." He was quite hungry now, and observing that the upper part of the plants was loaded with long seeds, he soon gathered some of them. Removing the hulls, he ate the kernels and found the taste of them so pleasing and their effect upon his hunger so gratifying that he exclaimed, "Oh, you are indeed good! What are you called?" The plants replied, "We are called manomin."

These adventures and discoveries of Wenibozho have served as a foundation for many legends that have been handed down through generations of Chippewa, Menomini, and related Indians. In their childhood, this story excited their imagination, and as they grew older they came to have veneration for this fruitful grass that provides such palatable and nourishing food.

Manomin,[3] an Algonquian word meaning "good berry," is suggestive and descriptive. By most of the tribes of this linguistic stock, this grass and fruit are called manomin, and by the same name became known to the early white settlers of the upper Mississippi Valley. Many common names for this plant came into use when the French and English population increased in this region. By the French it was folle avoine, a name most frequently found in the earlier accounts of that part of North America around the Great Lakes. The English names for the plant are quite numerous. Such names as wild rice, Indian rice, squaw rice, Canadian rice, black rice, Indian oats, blackbird oats, wild oats, and water oats are found in the literature. This plant, however, is not a species of rice or of an oat, though the vernacular names so designate it. Some of these names are only locally used. For example, this plant is known only by the name of water oats to the older inhabitants living along the tidal streams in the south Atlantic States.

Among the adventurers who flocked to North America shortly after Columbus missed his way to India and discovered a new world, there was a sprinkling of naturalists who came to gather seeds and

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[3] Jenks, Albert Ernest, The wild rice gatherers of the Upper Lakes. Nineteenth Ann. Rep. Bur. Amer. Ethnol., 1897–98, p. 1024, 1900.

bulbs of plants that might be useful in the gardens, fields, and forests of Europe. Probably the most noted among them was Peter Kalm. Shortly after his return to Sweden he published in 1751 a small octavo pamphlet of 48 pages,[4] containing "a comprehensive summary of his observations on the habitat, use, and care of American plants which he considered of sufficient economic importance to warrant experimental introduction into Sweden." In the text Kalm says: "I have chosen this means to give an index and short account of some of the useful plants [a total of 126 species] the seeds of which I brought home wth me from North America where I made a journey at the command of the Royal Academy of Science."

In reference to wild rice, which is included in this collection, he records: "In North America where the plant grows wild, it is used as food by all the savage nations, who yearly collect quantities. Wild ducks are particularly delicious when the rice is ripe, for at that time they live on it almost entirely. If we could succeed in getting this rice to grow and ripen here we would have gained a great deal, for the wettest places would become as productive as fields if the plant would stand our winters. Cattle are more than greedy for the leaves and stalks. The greatest difficulty will be to find a method of sowing seeds so they will germinate. We still know very little about nature's method of sowing the seeds of plants growing in water."

This attempt to introduce this wild plant into Europe was likely a failure, for Lambert, in a paper presented before the Linnaean Society of London in 1804, states that "the seed of [this species] *Zizania aquatica* in a vegetating state from America was long a desideratum among the botanists of this country; for although seeds were received here at different times, yet none of them grew. At last, Dr. Nooth by the desire of Sir Joseph Banks sent them from the lakes of Canada put up in jars of water. As soon as they arrived they were sown in a proper situation, where they came up in a few days and the plants ripened their seeds extremely well in the autumn." This importation of seed was made in 1791.

Resident collectors, among whom may be mentioned Bartram and Clayton, also aided in this work and in addition supplied the botanists of the continent with material that greatly enriched the herbaria of many botanical centers of the Old World. In this way a specimen of manomin, called wild rice by the white man, got to Europe, where in 1753 it was described and named *Zizania aquatica* by the Swedish botanist Linnaeus. Until then the "good berry" plant was unknown to botanists, although for centuries it had fed many tribes of wild

[4] Larsen, Esther Louise, Peter Kalm's short account of the natural position, use, and care of some plants, of which the seeds were recently brought home from North America for the service of those who take pleasure in experimenting with the cultivation of the same in our climate. Agr. Hist., vol. 13, pp. 34, 43–44, 1939.

men and for nearly 200 years had supplied the food wants of many European adventurers.

This grass, indigenous to North America, is found from Lake Winnipeg to the Gulf of Mexico and eastward from the Rocky Mountains to the Atlantic coast. Throughout these latitudes, and in this area where conditions are favorable, it is conspicuous among the aquatic plants growing in shallow lakes and in slow-moving streams. In the extreme northern and eastern limits of this region it often covers several hundred acres. Within its natural range the species often occupies the small bays of the large lakes, covers the mud flats on tidal rivers of the Atlantic Coastal Plain, fills the lakelike expansions of rivers near their source, and grows luxuriantly in the quiet bends of sluggish streams. It is seldom found in the inland lakes with no outlets. It grows well on a variety of soils under fresh-water streams and lakes. Its best growth, however, is made wherever the plants can anchor themselves in a thick layer of mud, regardless of the kind of soil.

Zizania aquatica is an aquatic, annual, self-sowing grass having tall, erect, cylindrical, and hollow stems, which bear the inflorescence and four to six long leaves with flat blades, conspicuously marked by a very thick midrib (pl. 4). The slender stems have a comparatively thin wall, and when seen by transmitted light, they show thin, transverse partitions, dividing the internodal space into compartments, which gives the stems a light banded appearance.

The stems vary in height from 5 to 10 feet and in diameter from one-fourth to five-eighths of an inch. The taller plants are characteristic of the tidal flats and the shorter plants of the northern lakes and streams. Plants with stalks as thick as 2 inches near the crown are not unusual in southern marshes. In thin stands and among isolated plants a single plant may have many stems, some arising from the base of the mother stem, though frequently as branches from the first and second nodes.

The principal roots are slender, fibrous, and numerous and do not penetrate deeply into the soil.

The first leaves to appear are long and narrow. In the later and permanent leaves the basal part known as the sheath is thick and spongy in structure and completely wraps the stem, thereby adding much to its rigidity. The sheaths vary in length from 9 to 25 inches.

The blade is the free end of the leaf. In the terminal leaves it may be 2 to 4 feet long and from less than an inch to 1 inch or more wide.

The inflorescence (pl. 5) is borne on the last node of the stem. It consists of two parts—an upper, with slender straight branches bearing the female or seed-producing flowers, and a lower, with drooping branches bearing the male flowers.

The female flower is very simple in structure, consisting of lemma and palea that enclose a much-branched stigma and a comparatively small ovary. The lemma bears a long awn or beard. In the male flower, there are also a lemma and palea, which are much shorter than in the female flower. They enclose six bright yellow stamens.

The seed is long and slender and almost cylindrical (pl. 6, *A*, *D*). A thin brown hull made up of the lemma and palea encloses the kernel and bears a long, stiff, straight awn that is covered with numerous barbs or bristly hairs. The surface of the hull itself is covered with similar hairs.

The kernel of the southern plants averages 20 mm. in length and 1.4 mm. in width (pl. 6, *E*). In the northern plants the kernel has an average length of 12 mm. and a width of 2 mm. (pl. 6, *B*). There is a shallow groove on the ventral surface of the kernel in which a long embryo is concealed. When fully matured the kernel is purplish black in color.

Zizania aquatica has two rather distinct forms, and within each there are many variants. The form having broad leaves and long needlelike kernels grows along the tidal rivers emptying into the Atlantic Ocean and is also found locally in the interior as far north as southern Minnesota and Wisconsin. The form with narrow leaves and short thick kernels grows in the upper Mississippi Valley and eastward along the Canadian border.

In ascending a tidal stream such as the Potomac River, which is salty or brackish almost to the head of tidal water, the halophytic vegetation begins to disappear with the appearance of *Scirpus americanus*, a fresh-water rush quite resistant to brackish conditions. As the conditions become less saline, fresh-water plants begin to occupy the marshes, and principal among them is *Zizania aquatica*. If the *Zizania* marsh slopes gradually into a slow-running stream, several distinct zones of plants will be present. The deeper water will be inhabited by several species of *Potamogeton*, *Vallisneria spiralis*, and such free-swimming plants as *Lemna* and other duckweeds. In water less than 5 feet in depth, the yellow pond lily may occur.

The next zone is usually narrow and is populated with the pickerel weed (*Pontederia cordata*), which grows in approximately 2 feet of water. Having a very large root system, it is capable of holding its place in a moderate current and serves as a protection to the adjoining zone containing *Zizania aquatica*, the plants of which are not strongly anchored in the soil. Although such a marsh is inundated, the depth of water covering it varies with the condition of the tides.

The *Zizania* zone is broad and usually parallels the stream for some distance (pl. 3). The luxuriant growth of *Zizania aquatica* shades out most of its competitors, leaving it in possession of the

land except where the stand is thin on the margin of the stream. Here straggling plants of *Polygonum sagittatum* and species of *Sagittaria* and *Bidens* are sometimes present. On the land side of this zone the dominant species is *Typha latifolia*, which under conditions of less water and greater silt deposit may displace *Zizania aquatica*. The *Typha* area itself is soon invaded by *Peltandra virginica*, *Iris versicolor*, and several species of *Hibiscus* and *Polygonum*. As the marsh becomes more elevated and drier, shrubs and finally trees become dominant.

In the lakes of Minnesota and Wisconsin, just beyond the zone containing such submerged plants as the *Potamogeton* species and *Vallisneria spiralis*, the bottom is often thickly covered with plants having lime-encrusted leaves and stems called stoneworts. The *Zizania* area is usually bordered on the outside margin by several species of *Scirpus*, never by *Pontederia cordata* as along the Potomac River, and on the land side by *Carex*, though *Typha* is often present.

During early April in the vicinity of Washington, D. C., the seedlings of *Zizania aquatica* have already emerged from the muck-covered flats and are strong enough to stand erect when the tide is out, like seedlings in any grainfield. Within a week or 10 days after emergence the young plants have three leaves. Growth is slow at first largely because of the low temperature of soil and water and intermittent sunshine. During these days they are strengthening their grip upon Mother Earth, for good anchorage in the soil at this time reduces the hazard of being washed away by tides, especially the ebb flow. The protection of the marginal plants that they have in later life is lacking now. The plants become more robust as spring advances, and by June, where the stand is good, the growth gives the marsh the appearance of a low meadow. In another month the stems that have been concealed by the enveloping leaf sheaths during this vegetative growth begin to give some evidence of their existence.

The part of the stem embraced by the sheath of the last leaf is growing rapidly now and being confined within a narrow space distends the sheath into a spindlelike appearance. Ten days after the inception of this condition is perceptible, the panicle, which is the terminal of the stem, begins to emerge. The panicle emerges slowly, often requiring 7 days to free itself from this cover. It carries on its distal end the female flowers that bloom almost immediately upon emergence. They, at once, are receptive to wind-borne pollen from nearby or distant plants, for the male flowers of the same plant are still within the leaf sheath.

The male flowers on the lower part of the panicle hang like elongated bells, which open a few days later, revealing six yellow bodies like so many clappers, which are filled with pollen that is soon dis-

charged into the air to be carried by the wind to other plants. This pollen takes no part in the fertilization of the female flowers of the same flower cluster. The male flowers on long drooping branches arranged in whorls add beauty and symmetry to this tall, slender, stately plant attractively dressed with long, broad, hanging leaves.

The slender, flexible panicle, when fully protruded, may be 30 to 50 inches above the terminal leaf. On its topmost branches the seeds are developing very irregularly. As they approach maturity, which normally occurs within 15 days after fertilization, the seeds drop very readily, passing quickly through the water to the mud bottom below. They do not float and are soon anchored in a soft bed by the many bristlelike hairs on their outer surface. These structures, by their number and arrangement, serve to fasten the seeds more securely in the mud. Here they lie until the following spring, when the majority of them germinate.

Zizania seed cannot be kept in dry storage like other seed. To retain its viability it must be kept in a wet state and at a temperature that will prevent fermentation and control germination. There is no harvesting of this seed in eastern United States for human use. Many birds, however, feast upon it and in so doing assist in the natural sowing of enough seed to provide for next season's crop. The dense brown mat of fallen plants and crumpled foliage, which soon covers the marsh, will again look green in spring when the young plants, sprouting from this self-sown seed, push their way through and above this organic debris.

The birds that feed upon this maturing grain are the bobolinks and red-winged blackbirds. Late in August and early in September these birds may be seen in large flocks settling on the plants of *Zizania aquatica* at meal time, which continues throughout the day. The wading birds, such as the sora, feed upon the fallen seeds that lie in shallow water, or exposed on the ground, when the tide is out. Many species of diving ducks feed upon the seed that has settled in the mud.

The center of the largest area of this uncultivated grain is in the region of the adjacent sections of Minnesota, Wisconsin, Manitoba, and Ontario, which is crowded with alluvial-bottom lakes, serving as sources of many rivers that for great distances meander through a flat country and give the landscape the appearance of one immense marsh. The Fox River, on which the earlier explorers traveled from the Great Lakes region to the Mississippi River, may be taken as typical of such streams, filled for the greater part of its length with *Zizania*. The Indians [5] tell us that this river was made by a monstrous serpent that spent the night in the marshes between Lake Winnebago and the Wisconsin River. Having obtained during the

[5] Thwaites, Reuben Gold, Historic waterways, p. 153, 1888.

day enough food to satisfy its hunger, this creature at dusk crawled in among the vegetation covering this low land to sleep off the lethargy that accompanies a full meal. While it slept, the dew accumulated upon its body. At sunrise it awoke and shook the moisture from its back and in it wriggled toward the larger lake, leaving behind a chain of small lakes that now are expansions of the river that became the waterway to the great Northwest. In his account of ascending this river in 1673, Marquette says, "The way is so cut up by marshes and little lakes (pl. 8, fig. 1) that it is easy to go astray, especially as the river is so covered with wild oats [*Zizania aquatica*] that you can hardly discover the channel. Hence, we had good need of our two guides."

In many places throughout this region such conditions exist today, in normal seasons, from the middle of June until the first of October. When the waters are free of ice, usually about the middle of May, *Zizania* seed begins to germinate. Most of it was sown by nature early in autumn of the preceding year and some of it through accident by the Indians themselves in spite of their skill in harvesting the crop.

The seedlings grow very slowly at first, too weak to stand erect without the support of the water, which not only surrounds but covers them, often deeply. During this early growth, with their narrow leaves floating and reaching upward and outward, the plants appear, when seen from a canoe floating over an old *Zizania* bed, like so many hydrae seeking their prey. In less than a month the young plants push their leaves to the water surface, spreading them upon it in long streamers, which at a distance upon good light conditions give the lake the appearance of having a low verdant island. In approaching small beds of this plant, the emerging leaves could be taken, even at a short distance, for a thick growth of duckweeds. In this stage of growth, the plants are greatly exposed to wave action. By it they may be detached from the soil and brought to the surface of lake or stream, leaving only open water where a few days before the young plants give the area the appearance of a green field. Entire stands covering a hundred acres or more are often destroyed in this way. When water and weather conditions are favorable, the plants are strong enough in July to push their stems upward. A few weeks later the flower clusters begin to emerge. The stems are stronger now and have become more erect. Continuous sunshine and a mild temperature ripen the seed in about 3 weeks.

Among the Indians about this time the topic of conversation is "ricing," a word coined by the white man and used only in reference to harvesting this grain. The urge to assemble at their favorite lakes begins now to grow upon these people. They drift in singly and in

family groups, settling usually in a wooded spot overlooking the rice-beds. In a few days a camp of many families is established. The Indians' information on the crop is rather definite, for during the season the rice-producing lakes are frequently scanned by them to ascertain the stand, vigor of plants, and probable seed production. Besides their interest in the crop as a source of food and revenue, this harvest time is the great social event of the year. Within these camps life presents a picture that is quite primitive even though here and there are evidences of contact with the white man's world.

When it becomes known after an inspection that about one-fourth of the seeds appear ripe, the men and women and the older boys and girls take to boats (pl. 8, fig. 2).

The grain is harvested from canoes that may or may not be the handiwork of Indians. Narrow flat-bottom boats, made of planks and pointed at each end, are also used. These boats are made by the Indians and are as expertly handled by them as the canoes. Either type of craft is preferred to broad-bottom boats. The latter kind, because of difficulty in handling, destroys many plants and shatters much grain that would be gathered from a boat more easily handled. In using the narrow boats the gatherers may return to the crop as the seed ripens and this may be done two or three times. With the broad-bottom boats, which are used by the white men, only one passage over the ricebeds is ever made.

Our cultivated grain ripens rather uniformly, but not so with this wild plant. The harvest in a certain locality may extend over a period of 2 or 3 weeks when weather conditions are favorable and when the crop is in the hands of Indians. The white man who gathers this grain is not a conservationist. By heritage the Indian is.

Each craft is occupied by two persons, one who stands in the stern, using a long forked pole to push and guide the boat slowly among the plants, and the other usually a squaw, who gathers the grain, seated near the middle of the boat, facing the bow. With two small pointed sticks, about 30 inches long, one in each hand, the seated person runs one of the sticks into the plant growth, bending a few plants over the boat, and strikes the grain-bearing panicles with the other stick quickly and lightly. The grain, which is easily dislodged, drops upon the covered bottom of the boat or canoe. This performance is repeated on the other side of the boat and continued alternately while the boat is moving until 75 to 100 pounds of seeds have been gathered.

The harvested grain cannot be kept perfectly dry while in the boat. The added moisture is usually driven off by thoroughly airing the grain, spread out in the sun on skins, birchbark, blankets, or canvas. After the grain is dried in this manner for several days (though sometimes this step is omitted), it is put into a large iron

kettle or a galvanized iron tub, about 25 pounds at a time, and parched slowly over a wood fire, being constantly stirred with a paddle to prevent burning (pl. 9, fig. 1). Parching requires from 15 to 25 minutes, depending upon which of the above containers is used. The grain parched in the iron kettle requires more time for this process and usually is a better quality than that parched in a tub, probably owing to the fact that a uniform heat is more easily maintained in the former than in the latter.

The grain is now ready for the most primitive kind of a mill. This equipment, which may be termed a mortar, is a hole in the ground about 1½ feet wide and 2 feet deep and lined with a skin. When ready to operate, about 20 pounds of the parched grain is poured into this receptacle. A buck Indian (pl. 9, fig. 2), taking the part of a pestle, steps upon this loose pile of grain and with a half jump on one foot and then on the other, combined with a kind of shuffle, treads out the kernels. While supplying this power the Indian supports himself by poles driven into the ground near the hole. This process, usually called "jigging," detaches the hulls and completes the milling.

The mixture of kernels and hulls taken from the skin-lined hole is now put into a birchbark tray, about 30 inches long, 20 inches wide, and 6 inches deep, to be separated by means of the wind. A windy day is usually used for this purpose, yet in the hands of a skillful squaw the tray without the aid of wind becomes a very efficient fanning mill. The operator, while standing, holds the partially filled tray even with her waist and slightly inclined. At regular intervals she tosses the contents of the tray. After each toss, the kernels tend to fall toward the lower side of the tray and the hulls toward the upper side. After this partial separation the mixture is tossed higher into the air, and at the same time with a quick movement of the wrists the tray is turned forward, producing enough wind to throw much of the chaff several feet away. This operation is repeated until the chaff is completely removed. If the grain was fully matured when gathered and the hulls loosened and detached by parching and "jigging," this primitive method of cleaning leaves only the heavy kernels, which, after washing in several changes of water, are ready for cooking (pl. 6, *C*).

Some new methods of preparing the grain, brought about through intercourse with the white man, are gradually being used by the Indians. The primitive method of parching and hulling, however, although it does take time and labor, produces a product superior in quality to that so far obtained by the white man. The use of modern machinery for cleaning in place of the birchbark tray could be used to advantage and is now being considered by dealers who are seeking larger markets for this cereal.

The Indians known as wild-rice gatherers belong to the two great linguistic stocks,[6] the Algonquian and the Siouan. The former includes the Chippewa, Menomini, Cree, Fox, and other small tribes. Among the latter the principal tribes are the Sioux, Winnebago, and Assiniboin. Probably the Menomini and Winnebago were the first important tribes to enter the eastern border of the great wild-rice country, for when found by Nicollet in 1634 they were well established in the vicinity of Green Bay, an area now within the State of Wisconsin. They had migrated from the Atlantic seaboard.

According to Indian tradition the Menomini tribe has been identified with wild rice for remote ages. Their name is usually translated to mean "wild-rice people." It has been their belief that "whenever the Menomini enter a region the wild rice spreads ahead, whenever they leave it the wild rice passes."[7] In their economy agriculture had a very minor place. They lived almost exclusively on game and on plants requiring no cultivation. They put a high valuation on wild rice and considered it a gift from the spirit powers, and, for these reasons, this grain has always been an essential basis for their ceremonial feasts and offerings.

In 1852 the Federal Government assigned to this tribe a large timber tract on the upper Wolf River as a permanent reservation. Here they are today, no longer "wild-rice people" but foresters engaged in lumbering, having a tribally owned mill at Neopit that has been in operation since 1908. Within their reservation there are a few wild-rice patches, but they receive no attention because they are too small to produce a worthwhile crop. Although the Menomini do not gather wild rice today, they still use it ceremonially.

The Winnebago Indians were less nomadic than the other Siouan tribes and lived near the waterways in preference to a life on the plains, which the Sioux enjoyed so much. For food they, like the Menomini, depended upon fish, small mammals, wild rice, maple sugar, and berries.

When the Chippewa, one of the largest tribes north of Mexico, began to move westward, they were driven forward by the Iroquois, who occupied land that was not overstocked with game but was well suited for cultivation. These newcomers, being hunters, were not welcome by the tillers of the soil and were forced by circumstances to continue westward. As the Chippewa moved onward, they encountered the eastern bands of the Sioux Tribe occupying the lake region now a part of Wisconsin and Minnesota.

This part of the great central valley of this continent is filled with innumerable shallow lakes and sluggish streams that at one

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[6] Jenks, Albert Ernest, op. cit., p. 1038.

[7] Keesing, Felix M., The Menomini Indians of Wisconsin. Mem. Amer. Phil. Soc., vol. 10, xi+261 pp., 1939.

time contained an unfailing supply of food. To the red man centuries ago this region was a hunter's paradise. Besides wild rice and fishes and other water-inhabiting animals, it contained for the aborigines an inexhaustible supply of land animals too, the flesh and hides of which provided food and clothing. These natural resources were considered by the Sioux who first possessed them and by the Chippewa who desired them as tribal property of the greatest value, and each fought fiercely to get control of them. To these gifts of Nature should be added the beautiful and useful birch, the bark of which the original inhabitants and their descendants have used to cover their lodges, wigwams, and canoes. The bark of the basswood, too, has contributed much to the wants of these people.

Without a decisive engagement at any time, the struggle between these tribes for the full possession of this country continued at intervals for several centuries until 1862, when the Government removed the Sioux.

The Chippewa never had an undisputed control of these lakes, though for several hundred years they ventured upon them to gather wild rice, often at the cost of a heavy loss of life. The Indian who gathers wild rice in the United States today is of this tribe. His appraisal of these lakes and woodlands made centuries ago has not changed with the years. So, on many occasions, when new treaties had to be made to gratify the greed of the white man, the Chippewa Indians have asked our Government to give heed to their needs.

As late as 1863, Hole-in-the-Day, the leading chief of the Chippewa, addressed a pathetic appeal to the Great Father at Washington, which, in part, is as follows:[8]

> My people are unhappy and dissatisfied. I want to see them happy and contented. It is both to their interest and the interest of the white man that they should be so, and they require but little to make them so . . .
>
> The present treaty gives us little but swamps or marshes, where locations can be selected that combine all these elements of comfort and content to our people, that is, good land, game, fish, rice and sugar. Here, we have neither to any considerable extent. True, we may find a little rice and a few fish, but not sufficient for my people, not enough to save them from starvation. If a treaty were made with the Red Lake Indians, a tract of country of the best character for my people might be secured without any outlay of expense to the government: say that strip of land lying on the Wild Rice River between the 47° and 48° north latitude and east of the Red River. There is every advantage of good soil, game, fish, rice, sugar, cranberries and a healthy climate . . .
>
> This late treaty never will, never can satisfy our people. A reservation on the Wild Rice would satisfy them all, and they would leave their present homes and go to their new ones happily and with a feeling that a better future was before them . . .
>
> The sooner this is done the better, as it would have a tendency to quiet the discontent now existing among our people generally, by holding out to them a

[8] Report of the Commissioner of Indian Affairs for the year 1863, pp. 328–331.

prospect of a good and pleasant home somewhere near or in the valley of the Wild Rice . . .

Believe me, then, my Father, to be what my people always have been and what they and I now am, Your friend and the friend of the white man.

Wild rice has played an important part in providing subsistence to explorers and trappers who penetrated this great continent two or three centuries ago along the waterways that now separate the United States from the Dominion of Canada.

A traveler among the North American Indians during the years 1652 to 1684, after referring to his reception by the natives, states: "Our songs being finished we began our teeth to worke. We had there a kinde of rice, much like oats. It growes in the watter in 3 or 4 foote deepe." After comments on God's care over His creatures and a brief description of how the grain is gathered, he continues: "That is their food for the most part of the winter and doe dresse it thus: ffor each man a handfull of that they putt in the pott, that swells so much that it can suffice a man."[9]

In his Travels and adventures in Canada and the Indian Territories, Alexander Henry [10] tells us a hundred years later about obtaining from Indian women by barter 100 bags of this grain and adds that "without a large quantity of rice the voyage could not have been prosecuted to its completion."

An ample supply of wild rice was always included among the winter provisions for the outposts of the fur companies trading in this region. David Thompson [11] records in his Narrative of explorations in western America that a superintendent of a fur company in northern Minnesota and his men "passed the whole winter on wild rice and maple sugar." Under such circumstances he considered this grain "a weak food" and says that "those who live for months on it enjoy good health and are moderately active but very poor in flesh."

The old journals of the earlier hunters, trappers, and priests seeking adventure in this great wilderness of the north contain many stories about the use of this grain in fighting hunger when other food was hard to get. In the great outdoors, white men, like Indians, can retain health, develop endurance, and enjoy life on a very simple diet.

The aborigines of this country were fond of soups, broths, and stews thickened with wild rice.[12] To this day, their descendants have not lost that fondness. In addition to its simplicity, this dish has the char-

[9] Voyages of Peter Esprit Radisson. Transcribed from original manuscripts in the Bodleian Library and the British Museum. The Prince Society, Boston, 1885.

[10] Henry, Alexander, Travels and adventures in Canada and the Indian Territories, 1760–76, new ed., p. 241, 1901.

[11] Thompson, David, Narrative of explorations in western America, 1784–1812. The Champlain Society, Toronto, 1916.

[12] Smith, Huron H., Ethnobotany of the Meskwaki Indians. Bull. Publ. Mus. City of Milwaukee, vol. 4, p. 259, 1928.

acter of elasticity, which appeals to the Indians. With them mealtime is often visiting time. A meal started with 3 people may be increased to 10 or more before it is finished. The uninvited guests never seem to cause embarrassment. To provide for them it is necessary only to add water to increase the volume of the soup.

With a squaw as a cook a favorite dish in the camp of rice-gathering Indians has been wild rice, corn, and fish boiled together, called Tassamanonny.[13] This combination of foods has also tickled the palate of the white man, as may be judged by the enthusiasm of one who spoke of it in his later years as being "an object of early love." The Indian likes sweets and often eats his boiled rice with maple sugar.[14] He may also flavor his boiled rice with cranberries and his soup with blueberries. Boiling does not, as a rule, reduce the kernels to a paste, but should this condition occur, the pastelike mass is used by the Indians as a substitute for bread.[15]

Some Indians parch wild rice until the kernels burst open as popcorn does when heated, and eat it in this condition when away from camp.[15] Because of its keeping qualities, the parched grain is recommended to vacation campers for use in either the dry or boiled state. In the land of Ten Thousand Lakes where the parched grain is comparatively cheap and is usually a part of the daily meal, the woodman has the advantage of the man of the city, who must pay exorbitant prices for it to cover handling charges and profits. Under these circumstances wild rice in the city home is seldom used except on special occasions.

Knowing how some like the grain, we may assume that all would be just as enthusiastic "ffor each man a handfull of that they putt in the pott" and would exclaim with Wenibozho, "Oh, you are indeed good!"

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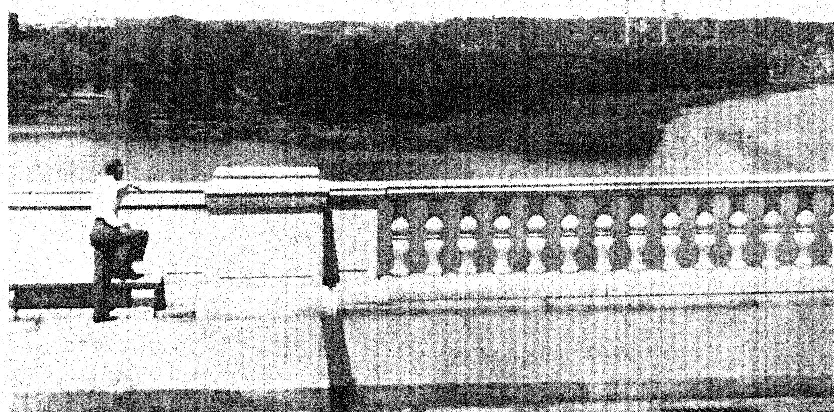
[13] Biddle, James W., Recollections of Green Bay in 1816–17. Appendix No. 4. 1st Ann. Rep. and Coll. State Hist. Soc. Wisconsin for the year 1854, vol. 1, p. 63.

[14] Dunbar, Sir George, Other men's lives, p. 149, 1938.

[15] Stickney, Gardner P., Indian use of wild rice. Amer. Anthrop., vol. 9, pp. 115–121, 1896.

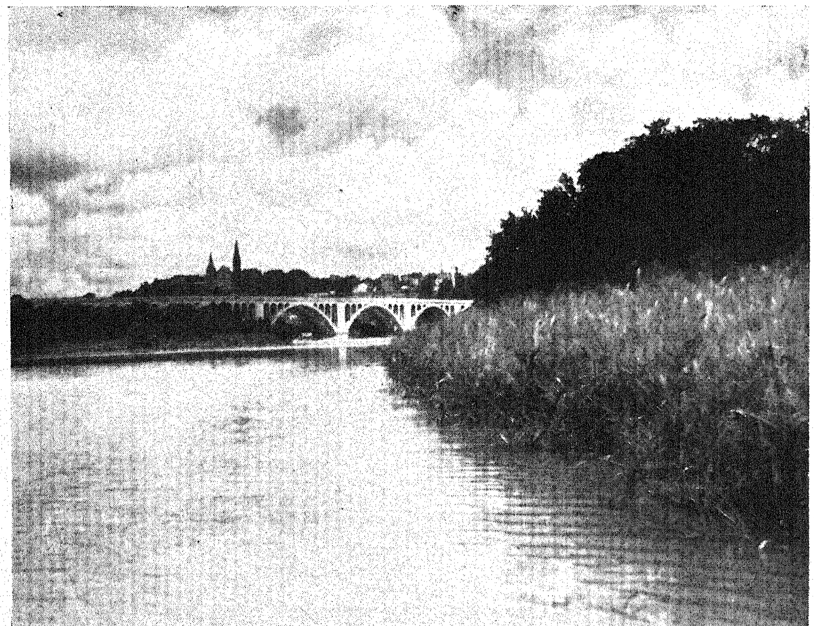
1. An airplane view of Theodore Roosevelt Island (Analostan Island), located between Memorial Bridge and Key Bridge, showing the broadleaf *Zizania aquatica* growing on its shore line, August 28, 1935. Official photograph, U. S. Navy.



2. A *Zizania aquatica* marsh on east side of Theodore Roosevelt Island (Analostan Island) viewed from Memorial Bridge, August 30, 1935.

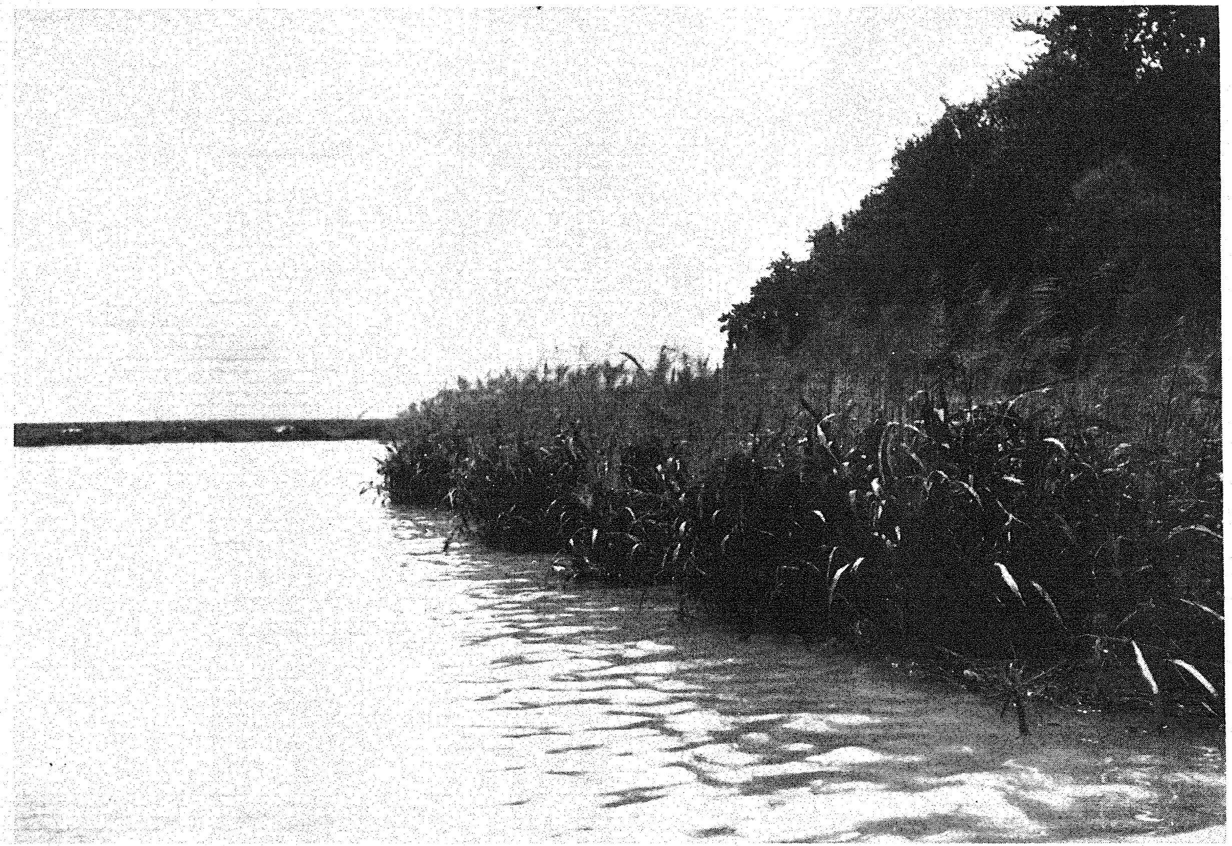
ZIZANIA AQUATICA IN THE DISTRICT OF COLUMBIA.

1. A NARROW ZIZANIA AQUATICA MARSH ON THE WEST SIDE OF THEODORE ROOSEVELT ISLAND (ANALOSTAN ISLAND), DISTRICT OF COLUMBIA, AND ON THE OPPOSITE VIRGINIA SHORE, AUGUST 20, 1935.



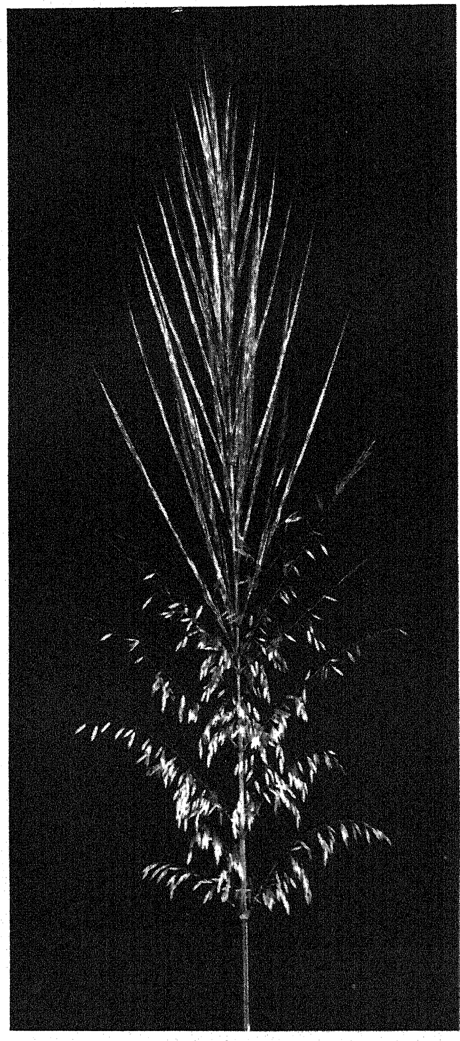
2. A ZIZANIA AQUATICA MARSH ON THE WEST SIDE OF THEODORE ROOSEVELT ISLAND (ANALOSTAN ISLAND), AUGUST 20, 1935.

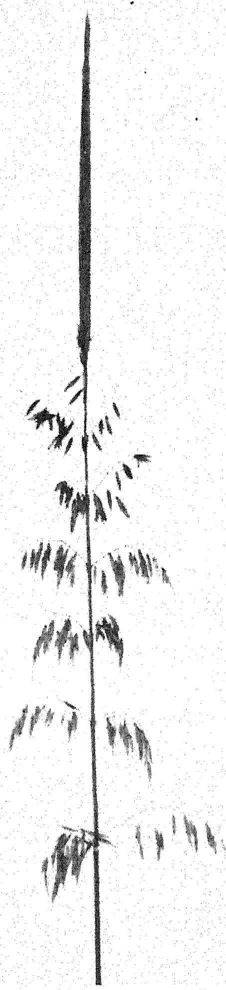
Key Bridge is in the background.



THE BROADLEAF ZIZANIA AQUATICA IN FLOWER IN NARROW MARSH ON EAST SIDE OF THEODORE ROOSEVELT ISLAND (ANALOSTAN ISLAND), FACING THE TITANIC MEMORIAL, DISTRICT OF COLUMBIA, AUGUST 20, 1935.

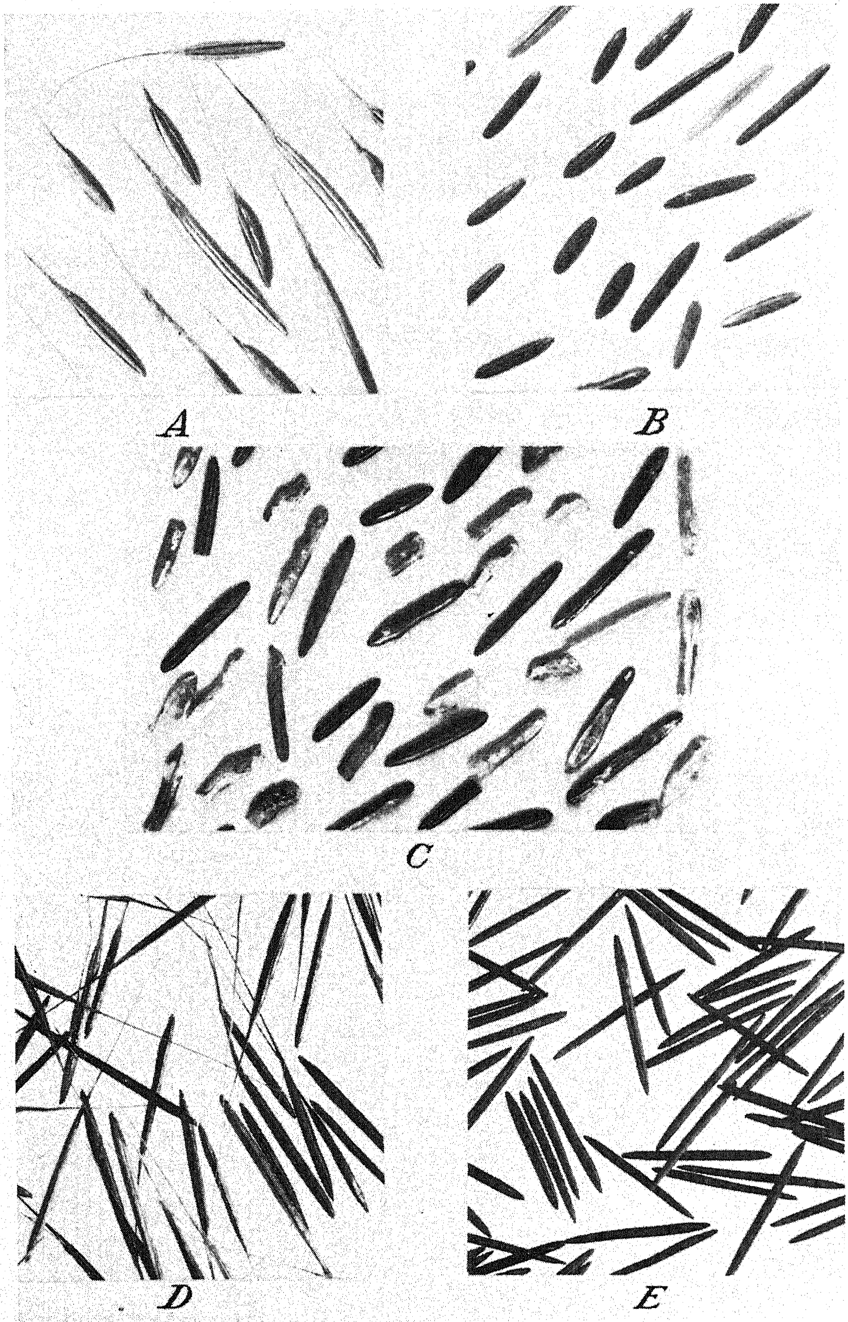
TYPICAL MATURE PLANTS OF THE BROADLEAF ZIZANIA AQUATICA GROWING IN A POTOMAC RIVER MARSH, DISTRICT OF COLUMBIA, SEPTEMBER 10, 1915.





PANICLES OF ZIZANIA AQUATICA.

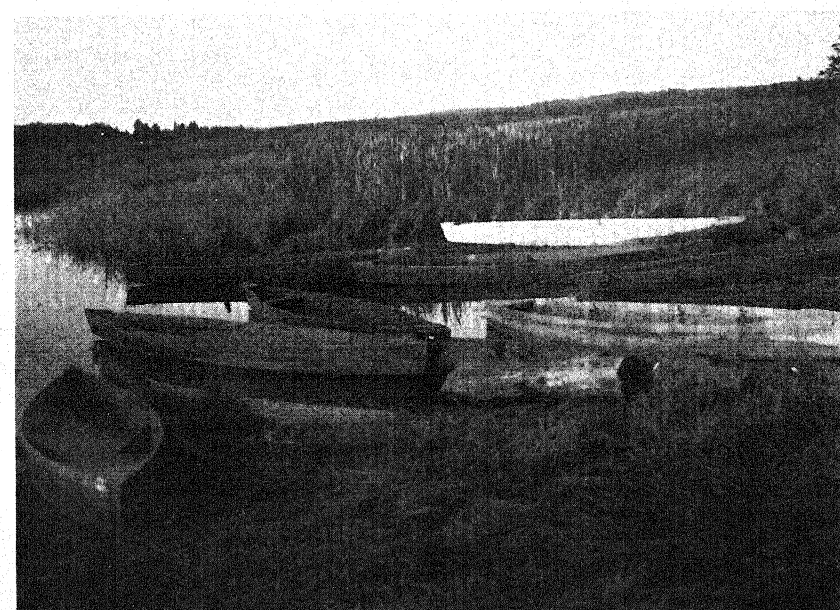
Left, the broadleaf form. Its natural length is 26 inches. Right, the narrowleaf form. Its natural length is 16½ inches.



SEEDS AND KERNELS OF ZIZANIA AQUATICA. (NATURAL SIZE.)

Narrowleaf form: *A*, seeds; *B*, kernels; *C*, parched kernels. Broadleaf form: *D*, seeds; *E*, kernels.

1. A TYPICAL WIGWAM OF THE CHIPPEWA INDIANS USED IN THEIR CAMPS DURING "WILD RICE" HARVEST.



2. NARROW FLAT-BOTTOM BOATS, MADE OF PLANKS AND POINTED AT EACH END, MADE BY THE CHIPPEWA INDIANS AND USED BY THEM IN HARVESTING "WILD RICE." CANOES ARE ALSO USED.

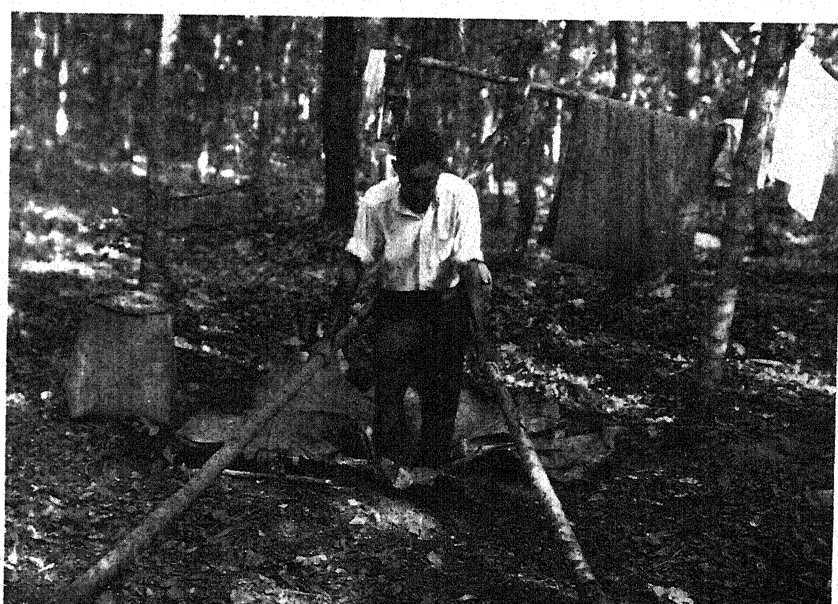
1. A SMALL LAKE IN NORTHERN MINNESOTA FILLED WITH THE NARROWLEAF ZIZANIA AQUATICA ("WILD RICE"). AUGUST 1938.

It has the appearance of a low meadow.

2. YOUNG CHIPPEWA INDIANS IN BOATS HAVE JUST FINISHED HARVESTING "WILD RICE" IN A MINNESOTA LAKE. SEPTEMBER 1938.

The plants are still erect, and there is no open water to be seen.

1. A CHIPPEWA WOMAN PARCHING "WILD RICE" IN A TYPICAL INDIAN CAMP, NORTHERN MINNESOTA. SEPTEMBER 1923.



2. A CHIPPEWA INDIAN HULLING ("JIGGING") PARCHED "WILD RICE" IN A TYPICAL INDIAN CAMP, NORTHERN MINNESOTA. SEPTEMBER 1923.

PREHISTORIC CULTURE WAVES FROM ASIA TO AMERICA [1]

By Diamond Jenness
National Museum of Canada, Ottawa

The recent excavations of Collins on St. Lawrence Island and at other places around the Bering Sea [2] seem to bring out one very important point, viz, that there has been no extensive migration across Bering Strait, unless it be of Eskimo, since the early centuries of the Christian Era. The Eskimo culture strata in that region show no profound disturbance such as one would expect from an invading horde, but rather a gradual change, stimulated to some extent by Asiatic as well as strictly American influences, but not by the intrusion of an alien people. Now Nordenskiöld and others [3] have proved that although a few Polynesians may on one or more occasions have reached the shores of America, there has never been any transoceanic migration large enough to affect profoundly the physical composition of the aborigines in the New World or the evolution of their cultures. We can rule out likewise any immigration by way of Kamchatka and the Aleutian Archipelago, if for no other reason than that the archipelago has yielded no traces of earlier remains than those of the Aleutian Eskimo, who undoubtedly reached their home from America. Bering Strait, therefore, was the only route of ingress into this hemisphere, and the forefathers of every known division of Indians must already have crossed this strait by the beginning of the Christian Era.

This conclusion harmonizes well with the results of linguistic studies. Hitherto we have utterly failed to link up any American Indian language with any language or group of languages in the Old World. Thus Rivet's effort to connect the Hokan dialects of California with Malayo-Polynesian, and some Patagonian languages with

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[1] Address of the retiring president of the American Anthropological Association, delivered at Chicago, Ill., on December 29, 1939. Reprinted by permission from Journal of The Washington Academy of Sciences, vol. 30, No. 1, January 15, 1940.

[2] Collins, H. B., Archeology of St. Lawrence Island. Smithsonian Misc. Coll., vol. 96, No. 1, 1937.

[3] Cf. Nordenskiöld, E., Origin of the Indian civilizations in South America. Comparative Ethnographical Studies, vol. 9, 1931.

Dixon, Roland B., The long voyages of the Polynesians. Proc. Amer. Phil. Soc., vol. 74, No. 3, pp. 167–175, 1934.

Australian, has apparently found few supporters. Some day we may succeed in joining up Eskimo with the Ural-Altaic languages and in proving that the Athapaskan or Déné tongues of North America are genetically related to the Sinitic tongues of eastern Asia. Such relationships, however, even if confirmed, must be exceedingly distant, for we know how little the Greenlandic Eskimo dialects have diverged from the north Alaska ones, despite a separation of 1,000 years, and how small is the difference, after an equally long separation, between the Navaho Indian dialect in the Southwest of the United States and the dialects spoken in the Mackenzie River Basin. Probably much of the linguistic diversity among the Indians and Eskimo took place in Asia before their entry into the New World; but the fact that no American tongue is palpably related to any Asiatic one strongly suggests that the inhabitants of the New World, barring the Eskimo to whom I will return later, separated off completely from those of the Old more than 2,000 years ago.

On ethnological grounds, too, there seems no reason to question this conclusion, because the traits that are common to Asia and America, apart from a few that are concentrated near the bridgehead at Bering Strait, are so widely diffused in both continents that they evidently carry a very respectable antiquity. Even the resemblances between the Palae-Asiatics and the Indians of the northwest coast of America hardly demand a migration in post-Christian times. If there was such a migration it is more likely to have been from America to Asia by way of the Aleutians and Kamchatka, as Collins has shown,[4] than from Asia to America; moreover, it was a relatively insignificant migration that introduced into northeast Asia a few cultural traits such as labrets, certain forms of stone lamps, a certain type of house, and perhaps some folk tales, but failed to effect any far reaching changes. It can hardly account for the much deeper resemblances, e. g., in physical type and clothing, between the Palae-Asiatics and some of the American Indians.

For the millennia that preceded the Christian Era, the millenia that saw the peopling and subsequent isolation of America, archeology, our safest guide, has afforded us hitherto only one or two uncertain clues. The main props for our theories have come from ethnology, linguistics, and physical anthropology, none of which can furnish more than the vaguest indications of a time sequence. In founding our theories on these disciplines we are building on shifting sand, and we need not be surprised if the theories topple over when the spades of the archeologists succeed in uncovering new and possibly unexpected remains.

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[4] Collins, H. B., op. cit., pp. 375–378. Also Culture migrations and contacts in the Bering Sea region. Amer. Anthrop., vol. 39, No. 3, pp. 375–384, 1937.

The geographical position of the Athapaskan Indian tribes along the pathway from Bering Strait toward the Equator, the late date (about A. D. 1000) when their advance columns reached the Southwest of the United States, the comparatively minor changes in their dialects from the Mackenzie Delta to Arizona, and the still demonstrable affinity of their language (if we may trust Sapir) to the Sinitic tongues of eastern Asia, all suggest that their movement into America did not long precede the Christian Era. There are faint indications that they may have entered this continent, or at least have advanced south from Alaska, in two waves, one considerably earlier than the other; for it is noticeable that the most divergent or archaic-seeming dialects (e. g., Haida and Tsetsaut) lie on the west side of the Rockies, where the snowshoe and the wooden toboggan so omnipresent in the Mackenzie River Basin seem to have been unknown in pre-European times. There are faint indications, also, that their irruption into the Mackenzie River Basin created a considerable displacement of other peoples who were occupying this region at the time, or were located on its outskirts.[5] A recent botanical investigation by Dr. Raup suggests that the grasslands of the Peace River area, perhaps, too, the forest zone along the northern edge of the plains, were muskeg land or tundra no longer ago than 2,000 or 3,000 years, and that the present-day bison and moose were preceded by herds of caribou. Presumably, the Eskimo of those days extended much farther south than they do now and were pushed eastward and northeastward by the invading Athapaskans. I incline to think that it was at this period that the Caribou Eskimo were restricted to their present home on the Barren Lands west of Hudson Bay; and that a kindred group of Eskimo fugitives occupied the coasts of the eastern Arctic, where they developed that mysterious Dorset culture, which extended in prehistoric times from Newfoundland to Greenland.

In addition to driving out the Eskimo, the Athapaskans may have dislodged some Algonquian tribes, as Birket-Smith believes, and started them on a movement that carried them into the Labrador Peninsula. Certainly the traditions of these Montagnais and Naskapi Indians bring them from the west, and the strange stone culture discovered by Strong near Nain,[6] on the Labrador coast, despite its distinctly Algonquian flavor, seems so alien to them that we may ascribe it tentatively perhaps to some early group that was later

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[5] Cf. Birket-Smith, Kaj, Folk-wanderings and culture drifts in northern North America. Journ. Soc. Americanistes Paris, n. s., vol. 22, pp. 26–29, 1930.

[6] Strong, W. D., A stone culture from northern Labrador and its relation to the Eskimo-like cultures of the northeast. Amer. Anthrop., vol. 32, pp. 126–144, 1934. Cf. the review by Wintemberg, W. J., in Geogr. Rev., Oct. 1930, p. 673.

absorbed or destroyed by other Algonquians, as were the now extinct Beothuk Indians of Newfoundland.

I am more reluctant to follow Birket-Smith in attributing to the Salish Indians of British Columbia an early home on the Canadian plains from which they were driven westward by the Athapaskans, because so many traits in Salish culture point to a southern rather than a Plains' origin, and their language, even should it prove to be Algonquian, as Sapir suggests, differs so widely from Blackfoot, Cree, and other members of that linguistic stock that it surely indicates a very long separation. Nevertheless, we must not overlook the possibility that the Salish Indians may have a dual origin, that they may be an amalgamation of two groups, one of which came originally from the south, and the other from the Canadian plains.

Shapiro and Seltzer[7] have pointed out the marked resemblance in physical type between the northeastern Algonquians (including the Hurons, who absorbed many Algonquians into their ranks), the Chipewyan Indians of Lake Athabasca, and large groups of Arctic Eskimo, particularly those in Coronation Gulf, Smith Sound, and Seward Peninsula. Now we know that at least the Coronation Gulf Eskimo, like those of Hudson Bay, dwelt inland only a few centuries ago. Hence physical anthropology also seems to indicate that the Eskimo and Algonquians formerly lived in such close contact, somewhere in the heart of Canada, that either the Eskimo freely took Algonquian wives or certain Algonquian groups adopted the Eskimo culture, and, under pressure from the invading Athapaskans, moved northward to the Arctic coast.

It is idle to speculate on the Asiatic home of the Athapaskans or the route they followed to Bering Strait. Even archeology may never be able to throw light on this question, because the majority of their tools and weapons had blades and points of bone rather than of stone, and bone disintegrates very rapidly. This, at least, is true of Canada. In Alaska there seems to be a greater wealth of stone implements, and there, too, we find pottery as far up the Yukon River as the mouth of the Tanana. Both these traits, however, may well be due to Eskimo influence, since no other American Athapaskan tribe was acquainted with pottery unless it bordered on a pottery-using people.

We may assume, then, until evidence to the contrary is forthcoming, that hordes of Athapaskan-speaking peoples crossed Bering Strait some time in the first millennium B. C. and forced their way southward, some by the way of the Mackenzie River, others down the

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[7] Shapiro, H. L., The Alaskan Eskimo. Anthrop. Pap. Amer. Mus. Nat. Hist., vol. 31, pt. 6, 1931; The origin of the Eskimo. Proc. 5th Pacific Sci. Congr., vol. 4, pp. 2723–2732, 1933.

Seltzer, Carl C., The anthropometry of the western and copper Eskimos. Human Biol., vol. 5, No. 3, pp. 312–370, 1933.

western slopes of the Rockies until they reached Colorado, Arizona, and New Mexico. It was they, perhaps, who introduced bows and arrows and the Mongoloid strain in Pueblo I remains, shortly before the end of the first millennium A. D.; they, too, who introduced the snowshoe and other important elements into America, as Birket-Smith cogently argues—though I find it difficult to ascribe to an Athapaskan invasion all the elements he includes in the snowshoe complex, particularly hunting territories, which I suspect are post-European, and moccasins, cradleboards, bark vessels, and the use of fatty substances for tanning skins, since these elements occur also in the extreme south of South America.

Inseparably linked with the Athapaskan invasion are the Eskimo, whom they partly dislodged, and the Indians of the northwest Pacific coast, the "totem pole" Indians whose origin and culture still remain a profound mystery.

Let us consider the latter first. Smith's excavations in the shell heaps along this Pacific coast have yielded rather negative results, although the forest growth proves that some of the heaps were abandoned at least 500 years ago and that their lowest levels must be several hundred years older. They revealed that there was a long-headed strain in the population that is absent in the modern Indians of the region; also that a few implements had a somewhat restricted range, being absent either in the more northern heaps, or in the more southern. By and large, however, there was little or no indication of any earlier culture than that which was still flourishing along this coast in the nineteenth century, although it was originally somewhat simpler, and more nearly related, apparently, to that found inland up the Fraser River. Even in the first millennium A. D., then, it was apparently well rooted in its present home.

As far as their physical type is concerned, the modern Indians of this area are indistinguishable, Hrdlička states, from the Gilyak and other tribes on the Amur River in Siberia; but the affinities of the earlier, long-headed strain are uncertain.

Linguistic studies indicate that Haida and Tlinkit are greatly modified forms of Athapaskan or Déné, that Tsimshian is a Penutian tongue related to some languages in California, while the three southern languages, Kwakiutl, Nootka, and Salish, may ultimately prove to belong to the Algonquian linguistic stock. This helps our present inquiry very little, except that it suggests a pressure of Athapaskan tribes in the north strong enough to impose the language but not to alter the physical type; and since the Haida and Tlinkit languages are so unlike each other, and so unlike other Déné tongues, it suggests also that they originate from the earliest Athapaskan wave and have undergone considerable changes since, partly owing to their isolation and partly to the influence of neighboring tongues.

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The evidence of ethnology is rather confusing. Several traits, notably weaving with loom and spindle, the sib and moiety system, and the chewing of "tobacco" with lime, suggest a linkage with the south and middle America. Others may have developed locally, e. g., plank houses, special types of twined basketry, the caste stratification, and the peculiar style of art. A few traits lead us northward; thus the whaling practices of the Nootka, and the decorated lamplike vessels of stone that were made by the Coast Salish, find their nearest if not their only parallels among the Eskimo. Several traits, however, carry us beyond the Eskimo right into Asia. There is slat armor, distributed almost continuously through Bering Strait (where it was used in the first millennium A. D.) to Japan and China; woven hats, a definitely Asiatic trait; curved fish knives, which recall East Asiatic curved knives as well as the Eskimo ulo; a musical style that seems altogether different from that of other American Indians, but, according to Barbeau,[8] so strongly Asiatic that certain songs practically coincide with northeastern Siberian ones, while others closely resemble Chinese Buddhist chants; and a social organization based on wealth rather than on descent or prowess as elsewhere in America, an organization that expressed itself outwardly in a potlatch system strongly reminiscent of Indonesia and Melanesia, and in totem poles and grave monuments that, despite profound differences, instinctively draw our eyes to the grave posts on the Amur River. Even the unique art of this northwest coast may offer a clue, because, as Collins[9] has pointed out, its eye designs resemble those of the mysterious Old Bering Sea Eskimo and also the eye designs on Chinese Shang Dynasty bronzes of the second millennium B. C. Finally, we have such close parallels in mythology between the northwest Indians and the Palae-Asiatic tribes of Siberia that Jochelson went so far as to postulate a backward movement of tribes from America into northeastern Asia.

We might also add in this connection two other elements not found on the Pacific coast itself but present among the Interior Salish Indians of the Fraser River Basin. One is the torpedo-shaped bark canoe, known elsewhere only from the Amur River in Siberia. The other is the semiunderground house, distributed all around the north Pacific Basin from China to the Southwest of the United States but in so many forms that the genetic relationship of them all is still uncertain.

We do not know, of course, the relative ages of all these traits common to Asia and the northwest coast of America. Some may be com-

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[8] Barbeau, Marius, The Siberian origin of our northwestern Indians. Proc. 5th Pacific Sci. Congr., vol. 4, pp. 2781–2784, 1933.

[9] Collins, H. B., op. cit., p. 298.

paratively modern, others very old. Some may have spread by slow diffusion, just as tubular pipes and the tobacco (*Nicotiana attenuata*) spread northward and reached the Fraser River only a short time before European occupation; others, again, may have been carried by a mass migration. Two or three of them, however, notably the social organization based on wealth, the talent for sculpture, and the music (if this is confirmed) appear so deeply seated that almost involuntarily we associate them with some invading people, a people whose original home lay somewhere, perhaps, around the Amur River. Yet whether such an invasion ever did take place, and, if so, whether it preceded or followed the Athapaskan invasion, must remain unsettled until we know more of the archeology of the north Pacific coast of America and also of northeastern Asia.

Archeology has made more progress with the Eskimo, the other people who appear to have been influenced by the Athapaskan invasion. Here I should like to pay tribute to the magnificent work of Danish scholars, not only the brilliant galaxy still living but the long line of their predecessors, from Hans Egede in the eighteenth century, Henry Rink in the nineteenth, to the last and in some respects the greatest of them, the late Knud Rasmussen. Thanks largely to Danish researches, supplemented by those of the Smithsonian Institution in Washington, we know that behind the modern Eskimo cultures there are three ancient ones, the Old Bering Sea in the west, the Thule, which originated in the west but spread over Arctic America to Greenland, and the Dorset, which was restricted to the eastern Arctic. The origins of all three cultures still await the results of further excavations in both the east and the west. Tentatively, however, I should advance the following hypotheses, in the hope that they may stimulate and guide the workers of the future.

In spite of suggestions to the contrary, I still believe that the third culture, the Dorset, is a genuine Eskimo one that has absorbed certain Indian traits, rather than an Indian culture that has Eskimoized itself, for the reason that we know of no Eskimo culture except the Thule that could have influenced it, and many of its non-Indian traits are equally non-Thule. Of special significance is the fact that a few of these traits seem to hark back to a very early Eskimo stage, because we have no parallels to them except in the far west. Collins [10] has already pointed out that in the Dorset, as in the ancient Aleutian and Old Bering Sea cultures of western Alaska, chipped stone implements immeasurably outnumber those implements of polished slate that are so characteristic of Thule and later times; also that Dorset art represents a fairly close approach to Old Bering Sea style I.

[10] Collins, H. B., op. cit., p. 373.

Let us examine these early eastern and western cultures more closely. In both the Dorset and the Old Bering Sea, but not in later remains, we find incurved side scrapers and trapezoidal knives of chipped chert, small slate implements with rubbed edges[11] that may have been boot creasers, and rubbing stones of polished crystalline rock, quartz in the east and basalt in the west. From an Aleutian shell heap, again, Hrdlička has brought back such typical Dorset types as small leaf-shaped blades notched on each side of the base, knives with curving edges like miniature hunting knives, and points with concave bases, the only difference being that the Aleutian specimens are chipped from crude basalt instead of the more amenable chert and quartz. One Aleutian knife (?) even has three notches on each side of the base, as we find on a few Dorset specimens also.[12]

Now we must not forget that in addition to these special forms known only from the east and the far west, the Dorset culture possesses many other old Eskimo traits, such as toggle harpoon heads, eyed needles and tubular needle cases, chipped end scrapers, polished stone adz heads and adzlike scrapers, barbed bone fish-spear points, stone lamps and pots, and even "jumping stones."[13] It is true that some of these objects have peculiar shapes, but there are others hardly distinguishable from Eskimo types elsewhere. Furthermore, the Dorset people possessed in full measure the skill of other Eskimo in carving bone and ivory, for in 1937 Rowley brought back from Iglulik, on the northwest coast of Hudson Bay, some excellent figurines of Dorset manufacture that rival in workmanship similar figurines from any period of Eskimo history.[14]

In view of all this, are we not justified in suspecting, not merely that the Dorset culture is genuinely Eskimo, but that it has stemmed from the same parent trunk as the ancient cultures of western Alaska?

If we accept this reasoning, then we must believe that the ancestors of the Dorset people separated from the western Eskimo before the flowering of the Old Bering Sea culture about the beginning of the Christian Era. This would date their entry into Canada not later than the first millennium B. C., and possibly even in the second millennium. The closing centuries of the second millennium B. C. appear in fact the more probable if, as I have already suggested, it was an invasion of Athapaskan tribes that pushed the Dorset people

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[11] In the Dorset culture implements of both slate and chert.

[12] At Kachemak Bay de Laguna found the following Dorset types: Planing adz blade, chipped asymmetric knife blade with notched tang, one type of harpoon head, needle, and dart heads barbed symmetrically and asymmetrically on both sides. (Frederica de Laguna, Archaeology of Cook Inlet, Alaska, p. 213, 1934.)

[13] "Jumping stones" have been discovered in Newfoundland and, more recently, inland from Hudson Bay, in the territory of the Caribou Eskimo.

[14] Rowley, Graham, The Dorset culture of the eastern Arctic. Ann. Anthrop., vol. 42, No. 3, pt. 1, pp. 490–499, July–Sept., 1940.

out to the coast of the eastern Arctic; for the Athapaskans themselves, as we have seen, must have crossed Bering Strait from Asia before the Christian Era.

Collins[15] has already pointed out certain features in which the Dorset Eskimo influenced later cultures in the eastern Canadian Arctic and in Greenland. He has shown that the modern form of the eastern harpoon head, with its bifurcated base and line holes on the upper surface, is probably derived from a Dorset type; also that Solberg's Stone Age culture in northwest Greenland represents a mixture of Dorset and Thule elements. Even the physical characteristics of the Greenland Eskimo may have been modified by Dorset admixture, since Greenland Eskimo skulls (outside of Smith Sound) resemble those of the old Birnirk Eskimo in the western Arctic (who were the immediate successors, if not the actual contemporaries of the Old Bering Sea people) more than they do Thule skulls from the eastern Arctic, or the skulls of Thule descendants in Smith Sound, Southampton Island, and Barrow.[16]

Let us turn our eyes again to the western Arctic, where Collins has so brilliantly deciphered the Old Bering Sea culture and traced its evolution, or devolution, down to modern times. The Birnirk phase of Barrow appears in his sequence as the immediate successor of the Old Bering Sea, marking the beginning of the Punuk culture. It seems rather strange, however, that its characteristic harpoon heads are made of bone instead of the usual ivory, and that they are rarely if ever decorated. Like the later Thule-type harpoon heads also present on St. Lawrence Island, they rest there uneasily as if they were intruders and did not belong to the strict order of succession, Old Bering Sea, Punuk, and modern. One wonders, too, why the Old Bering Sea art should have undergone a slow and gradual modification on St. Lawrence Island all through Punuk times, century after century, whereas at Barrow it vanished completely in the Birnirk stage.

Can it be that the St. Lawrence material is slightly misleading? The Birnirk (and its first-born child the Thule) is perhaps *not* a direct offspring of the Old Bering Sea, but both may be offspring of some less advanced culture that flourished on the northeast coast of Siberia around the mouths of the Kolyma and Indigirka Rivers. From this region the hypothetical parent culture may have sent its offspring eastward. One branch crossed over Bering Strait and proceeded north along the Alaskan coast to Barrow, blazing a trail that was followed by trading parties in later centuries; it still main-

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[15] Collins, H. B., op. cit., pp. 315, 336.

[16] Cf. Fischer-Moller, K., Skeletal remains of the central Eskimos. Rep. 5th Thule Exped., vol. 3, No. 1, 1937; and Skeletons from ancient Greenland graves. Medd. Grønland, vol. 119, No. 4, 1938.

tained connections with the south, however, since Geist[17] found a whetstone of Kobuk River nephrite in Old Bering Sea remains on St. Lawrence Island. The other branch colonized the coastline of Siberia southward from East Cape and either then or later established a few outposts on St. Lawrence Island. Subsequently, I suspect, the southern colony on the Siberian shore below Bering Strait, powerfully stimulated by a yet more southern source (ultimately, it may be, from China), revolutionized its style of art, and acquired perhaps some new elements, such as pottery and the bow drill, that appear to have been unknown in the still earlier period I hinted at before, the period when the ancestors of the Dorset people first crossed Bering Strait onto Alaskan soil and pushed into the heart of North America.

The reader may say, perhaps, that, like a fecund rabbit, I have already delivered too large a brood of unsubstantiated theories (some of them possibly still-born). Nevertheless I hope he will pardon me if I add one more progeny to the overabundant litter.

In Old Bering Sea remains on St. Lawrence Island Collins found many dog skulls that had been broken for their brains; and the dogs were of a smaller breed than those of Punuk and later times. Furthermore, objects associated with dog traction, such as toggles, flat bone sled-shoes, and whip ferrules, did not appear until the close of the Punuk period, or roughly 200 years ago, so that evidently the St. Lawrence islanders throughout most of their history never used dogs to drag their heavy-runner sleds. In the eastern Arctic, however, Mathiassen found numerous dog-harness toggles in Thule remains dating back 1,000 years or so; and the dogs that wore this harness doubtless belonged to that rather large and heavy breed so prevalent in the eastern Arctic today. Moreover, the Thule Eskimo, like the modern, seldom or never ate them, for Mathiassen remarked no broken dog skulls in any Thule site. No dog bones have yet been recovered from an unmixed Dorset site, nor have we found any sled toggles or harness toggles, though there are some flat, bone sled-runners. We read in Frobisher's Voyages,[18] however, that in the sixteenth century the Eskimo of Frobisher Bay, in the heart of the old Dorset range at the eastern entrance to Hudson Strait, kept two distinct breeds of dogs, a smaller one for eating and a larger one for dragging the sleds.

How are we to explain these facts? It seems to me quite possible that dog traction was unknown to the earliest Eskimo who reached America, not only to those who remained in Alaska, but to those, too, who pushed eastward into Canada and later spawned the Dorset

[17] Geist and Rainey, Archaeological excavations at Kukulik, St. Lawrence Island, Alaska. Misc. Publ. Univ. Alaska, vol. 2, p. 190, 1936.

[18] The three voyages of Martin Frobisher, pp. 136–137. Hakluyt Society, London, 1876.

people, and perhaps also the modern Caribou Eskimo. Both groups alike, however, kept a small breed of dog for hunting and for eating. Then, about the end of the Birnirk phase at Barrow, sometime in the first millennium A. D., a larger, sturdier breed of dog was introduced into Arctic America from Siberia, where dog traction, if not earlier than reindeer traction, arose as a substitute. About the same time, too, whaling originated in the same region or was introduced from Siberia also. Under the combined impulses of dog traction and whaling certain bands of these north Alaskan Eskimo trekked eastward, carrying their Thule culture with them; and in the eastern Arctic they encountered and merged with the Dorset people. Dog traction then became general throughout the whole of the Arctic, though St. Lawrence Island, being in a kind of back eddy, did not receive it until rather late. The smaller breed of dog in the west and east became extinct, but in Frobisher Bay a mixed group of Thule and Dorset Eskimo retained and ate it down to the sixteenth century, when it disappeared there also.

You will note that I have pictured the original homeland of the Eskimo, not in America, but in northeast Siberia about the mouths of the Kolyma and Indigirka Rivers. It would not surprise me if it were in this region, rather than in northern Alaska, that the Birnirk culture evolved, and even the subsequent Thule. Yet it is probable that the homeland as thus defined is far too narrow, that it should be extended westward. Certainly in post-Christian times there were Eskimo-like people far to the westward, on the Yamal Peninsula, for example, at the mouth of the Ob, where Chernezov has excavated three of their earth lodges,[19] probably also in northeast Russia, since the kayak and bidarka are reported from that region as late as the sixteenth century.[20] If some antecedent to the Old Bering Sea, Birnirk and Dorset cultures could be discovered on the Arctic coast of western Siberia, it would vastly lessen the gap, both in time and space, between the historic Eskimo cultures and those of the epipaleolithic peoples of northern Europe to which they bear a considerable resemblance.

In expounding his fertile theory of two culture layers in northern Eurasia and North America, an earlier coastal or ice-hunting layer and a later inland or snowshoe layer, Hatt justly signaled out the Eskimo as belated survivors of the ice-hunting stage who had adapted themselves to life on the seashore and to the hunting of sea mammals. If, as I have attempted to show, this adaptation occurred on the Arctic coast of Siberia, not later than the second millennium B. C. and

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[19] Cf. Zolotarev, A., The ancient culture of north Asia. Amer. Anthrop., vol. 40, p. 15, 1938.

[20] Cf. MacRitchie, D., Journ. Roy. Anthrop. Inst., vol. 42, pp. 493–510, 1912.

probably much earlier, then we should look for its inland predecessor in that "Siberian pocket" of which Zolotarev speaks, the Barstinsky Steppes, the upper Irtish, Ob, and Yenisei regions, and the narrow strip of territory extending to Yakutsk. Quite probably it will prove to be but one of many cultures, closely alike, that extended during epipaleolithic and early neolithic times from the Baltic to eastern Siberia. The snowshoe may have originated on the southern fringe of this zone, perhaps near the Lake Baikal region. At all events, the complex to which it gave rise seems to have contributed very little to the Eskimo cultures until relatively recent times, if we disregard the pressure exerted by its American carriers, the invading Athapaskans, on the Eskimo of eastern Canada. As far as we know today, the snowshoe itself first appears among the Eskimo in the Thule-age mound dwellings at Wales, Alaska, which may not be older than 6 or 8 centuries.

I have suggested that pottery, being unknown to the Dorset people, reached Bering Strait after some of the Eskimo had already entered America and wandered eastward. Richthofen [21] has drawn attention to the striking resemblances, particularly in decoration, between pottery found at Krasnojarsk and other places in Siberia, and pottery from the Algonquian or Woodland area in eastern Canada and the northeast United States. Following up this observation, McKern [22] suggests that "a culture closely related and directly parent to the Woodland Pattern, with pottery but without agriculture, originated in Asia, came into America and inland by way of the Yukon and Mackenzie Valleys, had a special development in a locale centering just south of Lake Superior to become what is now classified as the Woodland Pattern, and diffused from that center west, south, and east to its maximum area limits, which are not as yet well defined."

There are serious objections to this hypothesis. In the first place we have no evidence that any of the pottery found in this section of North America dates back beyond the Christian Era, and in more than one place, e. g., at Lamoka, we have discovered the remains of an earlier people who, like the Newfoundland Beothuk, did not use pottery. Secondly, not a single sherd of pottery is known from the Mackenzie River Basin or the upper reaches of the Yukon; and the pottery on the lower Yukon was probably copied from the Eskimo of the Punuk period. We have every reason to believe that no Athapaskan tribe ever made pottery unless, like the Sarcee, it was in close contact with a pottery-using people. It is true that we have found

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[21] Richthofen, B. Frhr. V., Zur Frage der archäeologischen Beziehungen zwischen Nordamerika und Nordasien. Anthropos, vol. 27, pp. 123–151, 1932.

[22] McKern, W. C., An hypothesis for the Asiatic origin of the Woodland culture pattern. Amer. Antiquity, vol. 3, pp. 138–143, 1937. Cf. also Fewkes, V. J., Aboriginal potsherds from Red River, Manitoba. Ibid., pp. 143–155.

sherds at a few sites along the southeastern fringe of the Mackenzie Basin—at Isle à la Crosse, Reindeer Lake, and Cree Lake—but only within the range of Cree penetration, and the sherds themselves resemble Woodland pottery from eastern Canada. In view of the vast potteryless gap separating this Woodland area from the Alaskan Eskimo, and the comparative lateness of pottery, apparently, in the Woodland area itself, it would seem more reasonable to believe that the latter acquired the idea of making pottery from the pottery-making peoples bordering them on the south than to connect them with the Krasnojarsk and other Siberian cultures so far removed in space, if not also in time. As long as the highway from Asia to America—that is to say, all Alaska outside the Eskimo area, and the whole of northern and western Canada—yield no sherds, we should cling to the theory that American pottery evolved quite independently of pottery in the Old World.

Beyond the second millennium B. C. we enter a realm of twilight, where ethnology almost ceases to flicker and archeology provides only one or two faint gleams to light our path. From the Gobi Desert in Mongolia, were Nelson [23] discovered a preneolithic microlithic culture of Azilio-Tardenoisian character, and Afontova on the Yenisei, where Von Merhart [24] suspects a microlithic station, we jump to the Amur River, whence other microliths are reported,[25] and from there to Fairbanks, Alaska, where microliths unearthed on the university campus seem to Nelson identical with his Mongolian finds.[26] Can it be that these mark a culture movement from Asia into America, and not merely a culture movement, but a movement of peoples?

Still more recently, and from Fairbanks also, it is reported that a stone spearhead resembling a Yuma type was found embedded in a small mastodon.[27] Now Yuma points are closely related to the Folsom complex, the oldest yet known in America, dating from a period when the camel, the mammoth, the mastodon, and other animals now extinct were still comparatively abundant. Because we have hitherto discovered no trace of this complex outside of the United States and the Canadian prairies, certain writers have suggested that it is a purely North American development. As Nelson [28] points out, however, we must continue to assume that its ancestry lies in the Old World until we find in North America a still older and more primitive industry

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[23] Berkey, C. P., and Nelson, N. C., Geology and prehistoric archaeology of the Gobi Desert. Amer. Mus. Nov., No. 222, 1926.

[24] Von Merhart, Gero, The palaeolithic period in Siberia: Contributions to the prehistory of the Yenisei region. Amer. Anthrop., vol. 25, pp. 45–46, 1923.

[25] Sovietskaya Archaeologiya, No. 1, quoted in Antiquity, Dec. 1937, p. 497.

[26] Nelson, N. C., Notes on cultural relations between Asia and America. Amer. Antiquity, vol. 2, pp. 267–272, 1937.

[27] Amer. Antiquity, vol. 3, p. 188, 1937.

[28] Nelson, N. C., Amer. Antiquity, vol. 2, p. 320, 1937.

from which it can be derived. This Yuma-like spearhead at Fairbanks should encourage us to search for the complex farther north and west, right into Asia itself.

The Fairbanks discoveries are intriguing from another standpoint. They appear to disclose one of the stations on man's journey from the Old to the New World, thereby enabling us to map out his route. Many Eskimo have journeyed from Bering Strait round the Arctic coast of Alaska to the Mackenzie River Delta, following a route that was probably open in early postglacial times also. It may, indeed, have been easier at that period than today, for the climate was perhaps milder and the Mackenzie Delta not quite so far north. The discoveries at Fairbanks seem to indicate, however, that some at least of the early migrants passed up the Yukon Valley, crossed to the eastern side of the Rockies (probably over the low divide at the headwaters of the Liard River), and traveled down the eastern foothills of the mountains into the United States. Some of the later migrants may have traveled down the western side of the Rockies also, but in early postglacial times this route was probably blocked by ice.

MASKED MEDICINE SOCIETIES OF THE IROQUOIS

By William N. Fenton
Bureau of American Ethnology

[With 25 plates]

INTRODUCTION

The Iroquois of New York and Ontario are among our oldest reservation Indians. Since the Revolution they have occupied diminishing areas within their ancient domain, and during the last century their settlements have been within marketing distance of large white trading centers that have become important eastern cities. It is a curious circumstance that Iroquois culture has not entirely disappeared in the face of our own civilization. Perhaps this is because it is only recently that the cities have grown and reached out to engulf the reservation communities. The older Indian people complain increasingly that the modern generation are failing to learn Indian languages or participate enthusiastically in tribal ceremonies. Nevertheless, within a day's journey from New York City there survive five conservative Iroquois communities in which, semiannually in spring and fall, the faithful leaders of the Society of Faces manage to muster enough ragged zealots to wear wooden masks and drive disease from their houses. The ethnologist may then, if he chooses, witness ancient ceremonies almost in his dooryard without going to the Southwest.

Longhouse groups.—The conservative Iroquois communities are located near the centers where Handsome Lake, the Seneca prophet, preached during the first 15 years of the nineteenth century, and on the reserves to which his disciples emigrated. These "real" or "longhouse people" live clustered about a dance house or ceremonial structure, called the longhouse, where they gather for social and religious purposes. The longhouse fires yet burn on the Onondaga Reservation near Syracuse (pl. 1, fig. 1) and on the three Seneca reservations neighboring Buffalo. The so-called Pagan Senecas kindle their fires at Tonawanda, at Coldspring on the Allegheny River, and at Newtown on Cattaraugus Reservation. Descendants of the Iroquois who moved west of the Niagara River into Canada at the close of the Revolution to settle along the banks of

the Grand River in Six Nations Reserve comprise four bands of Handsome Lake's adherents. The Upper Cayuga have their longhouse at Sourspings, Onondaga longhouse stands by Mackenzie Creek opposite Middleport (pl. 1, fig. 2), nearby is the third or Seneca longhouse with a congregation of mixed Onondaga, Cayuga, and Seneca descent, and the fourth longhouse is down below Peter Atkins' corners among the stronger band of Lower Cayuga. The Oneida near St. Thomas, farther west, have a longhouse, but neither among the Oneida, who early came under New England Christian influence, nor among the Catholic Mohawks of the St. Lawrence, who have recently been missionized from Onondaga, is there any great number of longhouse people.[1] As might be expected, the rituals of the masked shamanistic societies are best preserved in the more conservative centers of the Seneca and among the mixed Onondaga and Cayuga of Grand River.

Ethnological importance of collections.—Wooden masks from the Iroquois that are prominently displayed in eastern museums have considerable ethnological importance as well as popular appeal. Lewis H. Morgan seems to have been the first to collect Iroquois masks, and the literature on the so-called False-faces begins with his publication in 1851 of a line drawing of a mask, which he had acquired among the Onondaga of Canada, together with a terse statement of beliefs regarding the False-faces, the organization of the band, a reference to their preventing a cholera epidemic at Tonawanda in 1849, a description of their curing activities, and the depredations committed by small thieving boys disguised as False-faces at the Midwinter Festival.[2] Although J. V. H. Clark made somewhat earlier observations of the False-faces in the Onondaga Midwinter Festival of 1841,[3] the articles by DeCost Smith, the artist, are more reliable as source materials.[4] Smith drew the attention of the Reverend William M. Beauchamp to the function of the masks, which he had discovered in an Indian's attic, and to the problem of their antiquity among the Iroquois.[5] Besides his articles, Smith executed a series of animated illustrations which he deposited with his mask

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[1] For a map and summary of populations of reservations and settlements of modern Iroquoian peoples see the author's recent paper, Problems arising from the historic northeastern position of the Iroquois. Smithsonian Misc. Coll., vol. 100, pp. 214–215, 1940.

[2] Morgan, L. H., League of the . . . Iroquois, vol. 1, pp. 157–160, 204–205, New York, 1901.

[3] Clark, Joshua V. H., Onondaga; or reminiscences of earlier and later times, vol. 1, p. 57, Syracuse, N. Y., 1849.

[4] Smith, DeCost, Witchcraft and demonism of the modern Iroquois. Journ. Amer. Folklore, vol. 1, pp. 184–194, 1888; Additional notes on Onondaga witchcraft and Hoⁿ-do'-i. Ibid., vol. 2, pp. 277–281, 1889.

[5] Beauchamp, William M., Aboriginal uses of wood in New York. New York State Mus. Bull. 89, p. 187, 1905.

collections in several museums.[6] Somewhat later David Boyle, of Toronto, was stimulated to make similar observations of the False-face ceremonies among the Iroquois of Grand River and to publish brief notices of his collecting activities.[7] His collections now repose in the Royal Ontario Museum of Archaeology in Toronto along with the Chiefswood Collection of Pauline Johnson, the Mohawk poetess.

Several large study collections resulted from the activities of Harriet Maxwell Converse, a poet and journalist, who during the years 1881 to 1903 was an enthusiastic collector of Seneca Iroquois materials. Her success was partly due to adoption by the Senecas and later by the Onondagas, who installed her as an honorary chief of the Six Nations.[8] There are over 100 Converse masks in the New York State Museum (in Albany), and others in the Peabody Museum of Harvard University and in the American Museum of Natural History (New York); and Joseph Keppler, her successor among the Seneca, has deposited his mask collections in the Museum of the American Indian. However, Converse's brief published utterances on masks (1899 and 1908) and the accession records which sometimes accompany her collections make one suspicious of her field work. There are poetic titles for the masks, suggesting fanciful roles, such as "war and scalp, clan, maternity, bird, pipe-smoker's, sun-rise, dead chief, etc.," that no field worker among the Iroquois since her time has substantiated.

M. R. Harrington,[9] who visited the Canadian Iroquois in the summer of 1907, turned over to the American Museum gratifyingly full accession records which suggest only a few rather general mask types that agree with the findings of Morgan, Smith, Parker, and the writer. Even Parker himself, who had access to Mrs. Converse's notes and to some of her informants, found only four classes of masks based on function.[10] We conclude, therefore, that Mrs. Converse wrote into the records more than she was told, or that she posed leading questions to willing informants who politely assented.

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[6] The Onondaga Historical Society of Syracuse has the masks that Smith presented to Beauchamp, but the American Museum of Natural History has the masks that he published and his drawings. Following his recent death, his remaining collections were divided between the latter institution and the Museum of the Amercan Indian, Heye Foundation.

[7] Boyle, David, Society of the False Faces, Ontario Arch. Rep. 1898, pp. 157–160, 1898; and Iroquois medicine man's Mask. Ibid., 1899, pp. 27–29, 1900.

[8] Converse, H. M., and Parker, Arthur C., ed., Myths and legends of the New York State Iroquois. New York State Mus. Bull. 125, pp. 17–29, 1908.

[9] Harrington, M. R., Some unusual Iroquois specimens. Amer. Anthrop., n. s., vol. 11, No. 1, pp. 85–91, 1909.

[10] Parker, A. C., Secret medicine societies of the Seneca. Amer. Anthrop., n. s., vol. 2, No. 2, p. 179, 1909.

The False-faces raise some problems of theoretical importance. We may, as Goldenweiser suggested,[11] consider the wood-carving process from the standpoint of technique and artistic styles; or we may consider the organization of the Society of Faces (the False-face Company) and its relation to other medicine fraternities and show how their function is in turn patterned by the concept of reciprocal services between the dual division of Iroquois society. Thus every ceremony is conceived as being given by one half of the tribe for its cousins, the opposite half.

Finally, when we speak of masks, we must always remember, as Hewitt[12] stoutly insisted, that the "Faces" are really "likenesses," in the sense that they are portraits of mythological beings, and they are not masks for the purpose of concealment. The mask itself is only a symbol which operates on the principle of substituting a part for the whole, and the wearer behaves as if he were the supernatural being whom he impersonates. These supernaturals are Wind or Disease Gods of two classes and several varieties, and they are portrayed by wooden or husk faces that are described in the myths, but their human counterparts show a great deal of individual variation.

The need of an adequate study.—Our extensive collections of Iroquois masks are frequently undocumented or labelled so as to conform to rather dubious sources and in direct contradiction to the concepts which the Iroquois themselves hold regarding the masks and their function. Instead of catalog entries, the masks are attended with a lore that has come down through successive curators as to their supposed function. It is therefore not strange that the functions which have been ascribed to the masks on the basis of their appearance and the classification that has grown up in the museum differ from the ideas entertained by the Iroquois who still use them. At some time in the past two streams of culture have diverged, and I feel that the Iroquois have been the less speculative and therefore the more trustworthy custodians of tradition. That such confusion exists in the face of a rather extensive literature on

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[11] Prof. A .A. Goldenweiser and F. W. Waugh studied the Iroquois at Grand River for the National Museum of Canada following 1912. Masks interested both men: their role in society and the development of artistic styles intrigued Goldenweiser, the sociologist; while for Waugh, masks were part of material culture. Both men joined forces to record the carving process. Goldenweiser, A. A., On Iroquois Work, 1912. Summ. Rep. Geol. Surv. Canada for the calendar year 1912, pp. 474–475.

[12] J. N. B. Hewitt during many years of field work was interested in the problem of the "Faces." His informants, Chiefs John A. Gibson, Joshua and John Buck, Jr., were the best available among the Iroquois of Grand River. Neither his publications (Seneca fiction . . . (with Jeremiah Curtain), 32d Ann. Rep. Bur. Amer. Ethnol., pp. 61, 67, 1918; Iroquoian cosmology, pt. 2, 43d Rep. Bur. Amer. Ethnol., pp. 533, 610, 1928; The culture of the Indians of eastern Canada, Expl. and Field-work Smithsonian Inst. in 1928, p. 182, 1929; and ibid., 1929, p. 201, 1930) nor his manuscripts on the Faces provide the least support for Mrs. Converse's imaginative titles.

the so-called False-faces only serves to emphasize the need of an adequate monograph. Such a study would require a description and classification of masks in terms of the myths in which they figure and in terms of the rituals in which they participate. It would be interesting to know whether this classification agrees with a typological classification based on the masks themselves. It is important to know how individuals join the Society of Faces. How is the Society organized internally, and how is it related to other Iroquois medicine societies? This requires a detailed account of the rituals and a study of its ceremonial equipment and procedure. Finally an estimate is needed of the importance of masked shamanism in Iroquois life, and of its position in the ethnographic perspective of the Northeast.

Some years ago while engaged in field work among the Seneca I approached these problems in a general paper.[13] Its publication elicited rather unexpected responses representing a wide range of reading interests outside of ethnology, and it soon went out of print. Masks evidently hold an especial fascination for dramatists, sculptors, and decorators, and a great variety of hobbyists; while shamanism has implications for medicine and all those professions that hem in the periphery of the human psyche.[14]

Purpose.—The present paper attempts several things. First, it revises the original statement in an effort to clarify the unsolved problems that hung over from the first paper. Second, it includes new information from further field work among other Iroquoian groups and from the study of museum collections that were not available to me in 1935. Finally, it republishes the original materials together with the results of recent studies and makes them available to a wider public.

Problems.—The problems that confront us in the present study are essentially those of the relationship of mental stereotypes and overt behavior. First, what are the formal types of masks and how do the Iroquois classify them? To what extent do the mask types reflect cultural stereotypes given in mythology; and, conversely, to what extent are the formal character of spirits in the myths, and the shapes they assume in dreams and visions, projections into the spirit-

[13] Fenton, Wm. N., The Seneca Society of Faces. Sci. Monthly, vol. 44, pp. 215–238, March 1937.

[14] A number of general papers on masks and shamanistic societies have appeared. The relation of "Masks and moieties as a culture complex" has been considered by A. L. Kroeber and C. Holt (Journ. Roy. Anthrop. Inst. Great Britain and Ireland, n. s., vol. 50, pp. 452–460, 1920). Clark Wissler has made good use of the Iroquois material in a general paper on masks (The lore of the Demon Mask. Nat. Hist., vol. 28, No. 4, pp. 339–352, 1928), and Kenneth Macgowan and Herman Rosse (Masks and demons. Harcourt, Brace & Co., 1923) have discussed the relations of masks to the theater, reflecting the rather wide interest in the subject outside of anthropology.

world of the grotesque wooden masks worn by human beings?[15] If there are local styles of carving, we must consider how the individual learns to carve and the opportunities for the free play of his whims in devising new forms. There is always the problem of disregard of native theory in ritual practice. Thus, if there are formal distinctions between mask types, based on myths, the members of the society may not consistently use the same mask always to portray the same being, or to perform a consistent function in a ceremony. The history of masked shamanism among the Iroquois may help explain the relationship of the Society of Faces to the other medicine societies, the orders of membership, and the form and content of the masked rituals.

Method.—This study was first of all an attempt to find out the meaning and uses of masks in museum collections. I went to the Seneca at Allegany in 1933 with a series of photographs of masks that had been collected among them. Informants expressed great interest in pictures of their handiwork and they identified various masks as belonging to individuals who employed them in certain ceremonies, and I recorded these comments togethed with the Seneca names for various mask types. This procedure led to a number of myths and folk tales involving the masks, which I took down. The method was not standardized or controlled, but it was repeated with several informants who checked each other.

Direct information was solicited of all informants on origin myths and their personal histories as members of the Society of Faces. Case histories of members disclosed information on illnesses, membership through dreams and visions, hysteria, and accounts of participation in cures, as well as lengthy descriptions of the rituals.

Actual rituals of the masked societies were observed during field trips to the Seneca of Allegany and Tonawanda, and to the Onondaga outside Syracuse, N. Y.; [16] while only descriptions of the Cattaraugus Seneca and Canadian Iroquois masked ceremonies were obtained. However, observation provides only background for questioning because one observes both significant and accidental detail, and not until an informant describes the same performance does the ethnologist appreciate what the ceremony actually means to participants. Otherwise, the observer makes a complete but spurious record of behavior, and he fails to grasp what is culturally meaningful. A motion pic-

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[15] Goldenweiser, A. A., Early civilization . . . pp. 231–232, New York, 1922.

[16] Field work among the Seneca at Allegany from June to September 1933, and January–February and July and August 1934, was conducted for the Institute of Human Relations at Yale University. Two and one-half years at Tonawanda for the U. S. Indian Service afforded ample opportunity to witness the masked ceremonies. Recently, two seasons of field work among the Seneca of New York and among the Cayuga-Onondaga of Six Nations, Ontario, for the Bureau of American Ethnology have yielded much additional information.

ture record of the ceremonies would have the same weakness. Only during the last season have I been permitted to photograph the False-face ceremonies, but here again it has been more successful to have selected informants compose a series of what they consider the essential phases of a curing ritual. While the camera freezes characteristic posture and gesture, it also catches the contemporary scene. For this reason I had a young Seneca artist, Ernest Smith, of Tonawanda, make some illustrations of the False-face ceremonies, as he imagined they might have been performed a century earlier. At the same time he was executing an extensive series for the Rochester Museum of Arts and Sciences and his work entailed consultation with my older informants. Smith's illustrations, therefore, are to the photographs as informant descriptions are to the ethnologist's observations. They stand in the relationship of ideal patterns, cultural concepts, to actual practice.

Observation coupled with photography is particularly rewarding in studies of material culture. In this way I recorded the technique of mask making at Tonawanda, Coldspring, and Grand River, noting positions of work and ways of handling tools. Out of this emerged the best material on artistic styles, the role of the individual in devising new forms, education in handicrafts, and the tyranny of local canons of art. The whole mask-making process, which was formerly ritualized, is still hedged in by the fragments of a broken-down ceremonial procedure.

Because up to 1937 my data on mask types contained nothing comparable to the poetic titles that Converse had given to her masks, it seemed advisable to study her extensive collections in Albany and New York. I employed the technique of recording on slips information on a selected series of criteria that increased or narrowed as the study progressed, such as color, form of chin, mouth, nose, presence or absence of supplementary wrinkles and superorbital ridges, spines on nose bridge, shape and method of attaching tin eyes, presence of tobacco bags; and on the back: number of holes for head and hair attachment, indications of use, carving methods, species of wood, and other noteworthy features. Then each specimen was photographed with the aid of a copy stand, and negatives were cataloged serially to agree with data sheets and the museum catalog. Over 100 masks were examined at the New York State Museum, 6 at the Montgomery County Historical Society, Fort Johnson, N. Y., 24 at the Royal Ontario Museum of Archaeology, Toronto, and 16 of the older masks in the Rochester Museum of Arts and Sciences. Only 35, a small part of the extensive collections of the Museum of the American Indian, were examined at the Annex during 1 day, and photographs have been obtained subsequently of specimens on permanent exhibit

which it was not advisable to disturb. Other photographs have been generously supplied by Dr. W. C. McKern, of the Milwaukee Public Museum, the Peabody Museum at Harvard University, which I was unable to visit, and the United States National Museum, the National Museum of Canada, and the American Museum of Natural History.

In using photographs for sampling the knowledge of informants, I did not succeed in devising a controlled technique for testing and recording their attitudes toward the pictures. All informants regarded pictures of masks with great interest, and frequently with considerable amusement which they often shared with passing Indians; and the amount often varied with the horrific appearance of the mask and its supposed power, or sometimes as it furnished an excellent caricature of some local personality.[17] The Iroquois are both amused and awed by these pathetically humorous portraits of supernatural disease beings who so dominate their dream life. Nevertheless, if we did not obtain from all informants a consistent appraisal of mask types, very often an informant would recognize the picture as of a mask that he had made or one that he had seen in some ceremony, and all these incidents provided grist for our mill.

The pictures should prove of further value in segregating formal mask types and art styles by localities. It is possible to analyze the masks and plot the distribution of characteristic features, such as mouth shape, bent nose, spines on forehead, and presence of supplementary wrinkles. This is one way of establishing local and tribal styles. We compare these with concepts of informants and discover that much of formal art exists on the level of unconscious behavior patterns.

The practice of recording extensive texts in the native language of myths, prayers, and even accounts of individual participation in culture, has become a bit unfashionable of late in ethnology. This is partly because the texts often became an end in themselves, or they remained unpublished because the authors were not satisfied that they were accurately translated, or they reached such proportions that the translation became an impracticable ordeal, and the recorders passed away before the end was achieved. Nevertheless, in the study of ceremonies there is no substitute for texts in the native language. Very often the prayer texts contain archaic words that are the keys to unlock concepts that are not verbalized by contemporary members of society. Therefore, apart from any interest in linguistic research, I early discovered that I had to record texts to get at the ethnological materials which I was seeking. Thus from our texts we derive a name for the "sponsor" of medicine society ceremonies which we recog-

[17] Miss Marjorie Lismer, who was cooperating in the same study, encountered similar reactions.

nize in a similar form in the writings of the seventeenth century Jesuit missionaries, and from this we infer that the present role of "sponsor" has a historical depth of 300 years and that it is probably aboriginal. This helps to explain why the business of feast-making permeates all of Iroquois ceremonialism.[18]

Finally, to place the complex of Iroquois masked shamanism in ethnographic perspective the comparative method might be employed. If we can show that the complex has a historical depth reaching back to the first white contacts with the Iroquois, it would be relevant to investigate whether the Iroquois possess the complex in a greater degree of detail than their Algonquian neighbors. If we could determine the center whence masking spread throughout the northeast, some light might shine on the problem of whether Iroquois masking is a diagnostic trait pointing to their alleged southern origin, or whether it is related to northern shamanism and the use of masks across the Arctic littoral, or whether the complex was original with the Iroquois themselves from whom it spread to the neighboring Delaware. However, it is beyond the scope of this present paper to do more than stake out this problem.

MASK TYPES

The wooden masks or False-faces.—A few museum visitors may appreciate that the weird human likenesses which mock them from the showcases are actually memorials to generations of nightmares. They are wooden portraits of several types of mythical beings whom the Iroquois say only a little while ago inhabited the far rocky regions at the rim of the earth or wandered about in the forests. The Seneca term for mask is "Face" (gagǫ́hsa'); but the Onondaga more often call him "Hunchback" (hadu' 'i', or hǫdo· 'wi'(;[19] while the Mohawk are satisfied to use the term "Face" (gagų·'wara(; and so they are called "False-faces" in the literature, and in "reservation English." Iroquois hunters, when traveling, frequently met strange, quasihuman beings who darted from tree to tree in the forests and who frequently appeared to be disembodied heads with long, snapping hair. They agreed not to molest human beings, saying that they merely wanted Indian tobacco (*Nicotiana rustica* L.) and mush to be made from the white corn meal which hunters and warriors carried. However, the being with the wry mouth and broken nose, whom the Seneca call "Great defender" (s'agodyowe'hgo·wa·), "The great humpbacked one" (hadu'i' go· 'na') of the Onondaga, has appeared to few human

[18] For an elaboration of this method, see Sapir, E., Time perspective in aboriginal American culture . . . Canada Geol. Sur., Mem. 90, Anthrop. Ser. No. 13, p. 51 ff., Ottawa, 1916.

[19] *Phonetic note.*—The orthography employed in this paper has the same phonetic values as explained in Iroquois Suicide, Bur. Amer. Ethnol. Bull. 128, No. 14, 1941.

beings because he promised the Creator to abide in inaccesible places on the rim of the earth; but he is well known in mythology and by his human counterparts, the maskers that represent him in the ceremonies.

The Faces of the forest also claimed to possess the power to control sickness. They instructed the dreamers to carve likenesses in the form of masks, saying that whenever anyone makes ready the feast, invokes their help while burning Indian tobacco and sings the curing songs, supernatural power to cure disease will be conferred on human beings who wear the masks. The dancers should carry turtle rattles and speak a weird, unintelligible nasal language. They can scoop up glowing embers in their bare hands, without suffering burns when they blow hot ashes on the sick person. The masks are as varied as the visions and the artistic whims of the individual craftsmen who have carved them from single blocks of living basswood.

Native classification confused.—Natives themselves are confused when asked to classify False-faces. One old Seneca informant, Henry Redeye, told me there are as many False-face types as there are different people. Some are portraits of youths; others are of old men who have long, white hair and wrinkled faces. There are angry individuals with broken noses and mouths skewed to one side as if they had suffered paralytic strokes, who are apt to sweat and cause an owner illness if he neglects to supplicate them with tobacco offerings. Some have distended, open lips as if they were blowing ashes; a few with standing hair and raised eyebrows are whistling and merely want tobacco, while others protrude red tongues in pain, or laugh, revealing irregular rows of wooden or bone teeth. Their similarities are only those which the local culture has prescribed in dreams.

Tradition has dictated the forms which the faces assume in visions, and the features which the craftsmen emphasize when carving, the very features which the Indians mention when describing the original forest folk. It is sufficient for the carver to single out particular features of the face for artistic expression; the face portrays the being, and the wearer must dramatize his other attributes: his erect or slouching gait, his awful mien and the nonsensical, nasal speech which he accompanies by shaking a rattle. To the Indians, the total effect is both terrifying and extremely humorous.

Iroquois conceptions of the supernaturals whom these dramatizations represent have unquestionably been influenced by projecting in dreams the form of the masks and the behavior of the actors who appear in the ceremonies. Thus, as Goldenweiser pointed out: [20]

> Various grotesque spirits must be regarded as derived either from dreams or visions or to be the outgrowth of the free play of the imagination. Not infrequently, artificial objects or artistic conventions must have had an influence

[20] Goldenweiser, A. A., Early civilization, pp. 231–232. New York, 1922.

on the formal character of spirits. Thus, it is highly probable that the False-face spirits of the Iroquois are the projections into the spiritual world of the grotesque wooden masks worn by the members of the False-face Society, . . .

Mask types depend on the use to which they are put. They are not rigidly definable on the basis of form alone because to a large extent use determines type. This is the old argument of form vs. function, of native theory and native practice which flies in the face of all over nice taxonomic distinctions based on form alone. Aside from the fact that a carver may be guided by the mythological incident of hadú'i' breaking his nose on the mountain and intend his mask as a representation of that being, a subsequent owner may disregard this in using the mask. Conversely, a mask which was never intended to represent more than a common face of the forest may in time perform the curing role of the great world-rim dweller in the doorkeeper ritual. Thus all the old masks do become ultimately "doctor" masks. And, occasionally, even some of the more potent "doctor" masks get into the hands of small boys who impersonate the beggars of the forest at the Midwinter Festival. Therefore, only within certain limits and allowing for such exceptions will an informant even attempt to assign a series of masks to specific functions and categories.

The dramatic behavior of the wearers of the masks counts more in the roles in which the masks appear than the form of the mask itself. Here individual talent in acting and dancing constitutes much of the effectiveness of ceremony. Certain individuals in every Iroquois community are known to be good prospects for the role of doorkeeper. Sometimes a good actor possesses a fine old mask that is suited to the role, and in time both he and his mask come to be associated with this role. But as he grows older he may be selected as conductor and he easily finds a younger man to wear his mask, but the community ordinarily has little difficulty in distinguishing the mask and its owner and in identifying the new actor.

In general, the masks have deep-set eyes, rendered bright by metal sconces, and large, frequently bent noses. The arched brows are deeply wrinkled and sometimes divided above the nose by a longitudinal crease or a comb of spines, which only one Seneca calls "Turtle-tail," because they resemble the processes on a mud turtle's tail. The mouth is the most variable feature, and runs through a whole range of contortions depending on mood, function, or locality. Both mouth corners may be upturned in a smile, or a grimace showing teeth; or the mouth is distended ovally for blowing ashes, sometimes with protruding tongue; or it is puckered as if whistling, or puckered with conventionalized tongue and spoonlike lips, which may be again bifunnelate for blowing ashes, or once more revealing teeth; then others have large, straight, distended lips, which may be twisted up at one corner to accompany a bent nose, or down at the other

corner; and finally, both corners may turn down in an expression of utmost anguish. Thick, distended lips protrude beneath the nose, and a series of modifying wrinkles augment the distorted expression. Cheek bones are sometimes suggested, and a prominent chin, common on masks from Grand River, serves as a convenient grip for the wearer to adjust the mask to his face. The face is framed by a long wig, usually cut from black horsetails which fall on either side from a part in the middle of the forehead; but anciently, corn-husk braids, shredded basswood bast, or buffalo mane served as hair. Masks are commonly painted red or black.

Classification based on specimens.—In classifying the masks we must take into consideration formal types based on variations in the masks themselves and local styles of carving. Thus a particular formal feature, such as the bent nose or the twisted mouth, is apt to be shared among two or more local groups and tribes, but what distinguishes the masks of one local group, say the Senecas of Newtown, from the masks of artisans in another community, possibly the Onondagas of Grand River, is the manner with which the individual carver expresses his local artistic tradition in the general conformation of the whole face. Since the mouth is the mask's most variable feature, permitting us to range our photographs in a series of categories illustrating progressive changes from up-turned corners to down-turned corners, it seems a likely basis for distinguishing formal types. What gives this arrangement significance is the tendency of the Iroquois themselves to designate the mouth as a criterion for naming the masks. The masks, unlike individuals, do not have personal names except as they are given the names of the spirits who are their tutelaries. The names are rather descriptive referents to various facial expressions.

Thus one afternoon two Seneca informants, James Crow, of Newtown, and Chauncey Johnny John, of Coldspring, distinguished the following mouth types, while examining photographs of museum specimens. Naturally, they commenced with types most familiar to them in their own localities; and I append the remarks of other informants, Jesse Cornplanter, of Tonawanda, and Simeon Gibson (Onondaga-Cayuga), of Grand River, and Sherman Redeye, of Coldspring, where they seem pertinent. We begin at the middle of the series.

1. The crooked-mouth masks, a type so named because "his mouth is twisted" (haʻsagai·ʼdeʼ), are commonest among all the Iroquois. One corner of the mouth is pulled down, or up. They occur among Seneca, Cayuga, and Onondaga of New York and Grand River. In the latter place carvers make them intentionally horrific to frighten away disease, and masks with bent noses and twisted mouths aug-

mented by many supplementary wrinkles constitute a local style (pl. 2, fig. 2).

2. The mask with straight lips, a type so named because "his mouth is straight" (hodesado′gę̔dǫ), has straight distended lips like a duck bill across the whole face. This one, with its variants, together with the two that follow, is frequently ornamented with a crest of spines or "teeth" extending up the forehead from the nose bridge, but its symbolism is not clear (pl. 3, fig. 1).

3. The spoon-lipped or spoon-mouthed mask, with "double spoons made on it" (odo′gwa'šǫdǫ'), is the most easily recognized type. It consists of conventionalized flared lips or puckered lips as in blowing and a rudimentary tongue which projects beneath the pursed mouth aperture (pl. 3, fig. 2). Spoon-lipped masks are rare among the Iroquois of Grand River but are common at Newtown on Cattaraugus Seneca Reservation, and they have been in use since the earliest memory of my informants. The Newtown Senecas consider the straight-lipped and the spoon-lipped masks, which they pair in the doorkeeper ritual, to be classic Seneca representations of the great supernatural world-rim dweller. However, the spoon lips take the form of two funnels among the Seneca of Coldspring on Allegheny River.

4. The hanging-mouth mask is so named because "the corners of his mouth are hanging" (hosę·' ′dǫ'), not unlike the muse of tragedy (pl. 4, figs. 1 and 2). This seems to be an old type among the Senecas because it is present among collections made at the old Buffalo Creek reserve, Onondaga Valley, and Tonawanda; and one specimen is supposed to have been taken beyond the Niagara frontier into Canada before the Revolution (pl. 4, fig. 1). One such specimen was collected in Oklahoma, but it was probably taken there from Grand River, Ontario. These masks sometimes have a crest of spines on the forehead, but it is not a constant feature.

5. Masks with tongue protruding (dodänǫhgä′węh) as in pain were collected by DeCost Smith at Onondaga and by Lewis Morgan and David Boyle among the Onondaga of Grand River. It is relatively uncommon among the Senecas and may be considered an Onondaga type (pls. 5 and 6).

6. Not all the masks are wry-faced. Some of them are smiling (hoyóndiha'—he is smiling). As one informant remarked, "Maybe he saw a pretty girl and he is smiling." Smiling masks are frequently beggar masks, representations of the Common Faces of the forests. They are not confined to the Senecas of Coldspring, but the smiling masks from the Onondaga of Grand River are apt to be extremely heavy with thick, leering lips (pl. 7, fig. 2), a heavy chin,

and puffy cheeks; and some of these were unquestionably used in curing.

7. The whistler (hanǫ́·gaha‘) as his name implies has a puckered mouth, frequently enhanced by supplementary wrinkles. He is also called thebl owing spirit mask, or the Whistling God, Djinnaga'hihä‘. His likenesses occur among the Seneca and the Onondagas of Canada (pl. 8). They generally belong to the class of beggar or dancing masks and are not considered representations of the great world rim gods.

8. The divided mask represents a god whose body is riven in twain (dehodya'tgai·'ɛwę‘). According to Hewitt, who learned of him through Joshua Buck, his body is half human and half supernatural; hence his face is divided between deep red and pure black, symbolizing the east and the west, and he is free to wander at large even among the people. The Senecas, except a few at Tonawanda, are unfamiliar with him, and he seems to be a Cayuga-Onondaga spirit localized on Grand River where there are a few masks of him, which are not well known even there (pl. 9, fig. 1). It seems possible that the divided face concept was taken over from the Delaware who settled among the Cayuga.

9. *Other types of wooden masking.*—Longnose (hagǫ́nde's) masks are always taken as a joke by the Iroquois because they remind them of Longnose, the trickster, with whom they were threatened as naughty children (pl. 9, fig. 2). Probably very few of them were intended to represent the trickster, although such masks were anciently made of buckskin and later cloth to frighten children at Coldspring (pl. 10, fig. 2). A certain puckish wooden figure that stood before a Syracuse tobacconists, DeCost Smith was told, had inspired a few similar masks at Onondaga (pl. 10, fig. 1).

10. Horned masks (donǫ'gao·t—horns on it) are a relatively recent development at Newtown. According to Jesse Cornplanter, this so-called buffalo type of mask was first devised by Austin Jacobs about 1900, and since that time masks of this character have usurped roles that were formerly reserved for the "doctor" masks (pl. 11, fig. 1). Some of the horned masks have a decided diabolical or negroid appearance and were possibly intended as caricatures of white gods, or the other new race that came to live near the Senecas at Buffalo.

11. Animal masks are not as common among the Iroquois as among some primitives, and certainly they are few as compared with anthropomorphic likenesses. However, while I know of only one mask representing the Dew Eagle (S‘ada'ge'a·') or the Giant Raven (gáhgago·wa·), who is depicted as fetching in his bill the bloody scalp of the Good Hunter in the origin legend for the Little Water Society, masks representing the pig (gis'gwis) are fairly common

at Newtown (Seneca) and among the Cayuga of Grand River. At Newtown, James Crow formerly had a pig mask which was used as doorkeeper in a dream ceremonial constructed around the Delaware Skin-beating Dance. It is possible that pig masks are derived from masks representing the bear, but there is no evidence that such masks were used in the Bear Dance Society ritual. However, with the disappearance of the bear the pig has become the principal feast animal among the remnant Iroquois, and the pighead has acquired a reflected holiness by association with the rituals of the medicine societies (pl. 11, fig. 2). At Coldspring the pig is only a beggar mask who appears at the Midwinter Festival.

12. The blind mask (dágǫgwegǫ gagǫhsa') presents something of an enigma because it is either little known or informants are unwilling to discuss it. The former is apparently the reason because blind masks have been obsolete ceremonially for over a generation, according to J. Cornplanter, whose father remembered them from his youth. In the ritual of the I'do·s Medicine Society, the shaman demonstrated his power to see through the mask by juggling hot stones, and he knocked a standing doll from an inverted corn mortar. Furthermore, the masks of this ritual in the New York State Museum, which Parker published in 1909, do not appear to have had much use in ceremonies. Although a blind mask has been collected from the Seneca of Grand River (pl. 12), its use is unknown to my informants, the Gibsons. In this connection it is interesting that some Senecas think the black faces have more power because they usually have smaller eye holes than the red ones, but other informants say red masks are equally powerful, and James Crow said that to meet a red one might cause nosebleed. At any rate the red and black masks are about equally represented in our collections.

The husk faces or "bushy-heads."—Besides the wooden False-faces, corn husk masks represent another class of earth-bound supernatural beings who formed a pact with mankind and taught them the arts of hunting and agriculture. The techniques of twining and braiding corn husks in the manufacture of shoes, mats, and dishes is ancient among the Iroquois peoples, and it is one of the traits that point to a southern origin for those elements of their culture that are associated with the cultivation of maize. Nevertheless, the use of husk masks is probably no older than sewing braided corn husks for seats and foot mats, since the Husk Faces and the beings which they represent are named like the mats "bushy, fuzzy, or awry" (gadji·'sa'). The husk faces look like door mats, the only difference being that the masks have holes for the eyes and mouth and the pile is cut off on the inside, but they too have a ragged fringe of hair. Thus a person awaking with his hair standing awry, like the pile of a foot mat, in said to look like gadji·'sa'—a bushy-head.

Three techniques of manufacture produce as many types of husk masks. Most commonly long strips of corn husk braid are sewn in three coils which form the eyes and mouth, and the nose and fringe are added. The females of the species are designated by appending little knobs of covered husk to the fringe, eyes, and nose. The rougher looking ones are considered old men and the smoother ones are youths (pl. 13). Usually the mouths are small and round, but again they take on the mouth shapes of the Wooden Faces. At Grand River, husk faces are more coarsely braided and more completely cover the wearer (pl. 14, fig. 2).

Twined husk faces were until recently made by old Seneca women at Allegany, and at Cattaraugus only one old woman still makes them. The technique of twining involves twisting a pair of wefts around each radiating warp as it is passed until one reaches the rim of the mask. Twined masks are commenced at the nose (pl. 14, fig. 1). The poorly made ones with stubble on the cheeks are grandfathers, and the smooth-faced "bushy-heads" with a round red spot painted on each cheek are young people bound for religious festivals at the longhouse.

Among the Onondaga of Grand River, Canada, besides the masks made entirely of corn husks or wood, there is a third variety known as wooden bushy-head (owę''ga gadji·'sa'). This is a natural wood mask with undistorted human features having only ceremonial face painting confined to a round red spot on each cheek or a series of vertical lines beneath the lower lip. It has corn husk fringe as hair, and is credited with more power than the other husk faces (pl. 15, fig. 1).

Miniature masks.—For all the larger varieties of masks there seem to be miniature masks which take the characteristic types and art styles of the localities where they are made. These are either kept as personal charms or they are hung on the larger masks and "ride along" in the ceremonies (pl. 15, fig. 2).

HISTORICAL PERSPECTIVE

Archeology.—Stone faces and faces on pots and pipes occur in sufficient abundance throughout the historic area of the Iroquois to lead one to suspect that the prehistoric Iroquois entertained conceptions of supernatural beings like those which their historic descendants associate with the False-faces. The appearance of some of the human and animal faces modeled on the bowls of earthenware pipes, usually to face the smoker, suggests that they were intended to represent wooden masks. However, the archeological evidence further confirms an inference that we can make from the accounts of early travelers below, namely, that the False-face rituals made

their appearance among the Seneca of western New York relatively late in the seventeenth century considerably after they were first observed by the French at Huronia, because Wintemberg and Parker find that a type of pipe known as the "blowing face" was first evolved during the post-European period of Neutral, Huron, Tionontati, and Seneca culture.[21] Furthermore, during the colonial period the clay pipes were imitated in stone, and such a pipe with a blowing spirit mask facing the smoker has turned up recently near a late historic sugaring campsite of the Cornplanter band of Senecas (pl. 16).

Narratives of early travelers.—From the earliest European contacts with the Huron and Iroquois over 3 centuries ago, the explorers and missionaries, while they do not always specifically mention masks, at least describe ceremonies that are now connected with masks in the modern rituals. The behavior of the actors is older than the form of the masks, and it would seem that the ritualized Iroquois masked shamanism that we observe in practice today has kept alive old tricks of the Huron Oki or medicine man, who was not always masked. The Oki handled hot coals and blew ashes on his patient, and Champlain (1616) witnessed the hysterical frenzy of medicine men and neurotic women who walked "on all fours like beasts" until the masked company were summoned to displace their possession by blowing upon them to the din of their turtle rattles; and they "parade the length of the village while the feast is being prepared for the masquers, who return very tired, having taken enough exercise to empty the kettle of its Migan."[22] In another place he describes the beggar maskers, men and women, visiting each other's villages much as they now go from house to house at Midwinter. In 1623 Gabriel Sagard, whom Champlain invited to spend an exciting winter in Huronia, found the Okis still in business, and he witnessed an unmistakable example of the doorkeeper's role in the modern ritual. The actor wore a bearskin garb reminiscent of those in use among Delaware and Onondaga maskers of recent times, although a wooden mask is not mentioned.

> I have seen . . . a bear skin covering the whole body, the ears erect on top of their head, their face covered up except for the eyes; and these persons were only acting as doorkeepers or jesters and took no part in the dance except at intervals, because they were for a different purpose.[23]

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[21] Wintemberg, W. J., Distinguishing characteristics of Algonkian and Iroquoian cultures. Nat. Mus. Canada, Ann. Rep. 1929, p. 78, Ottawa, 1931; Roebuck prehistoric village site . . . Nat. Mus. Canada, Bull. 83, p. 75, 1936; Parker, A. C., The archeological history of New York. New York State Mus. Bull. 235, p. 146, 1922.

[22] Champlain, Samuel de, Voyages . . ., vol. 3, pp. 153–155. The Champlain Society, Toronto, 1929.

[23] Sagard, Father Gabriel, The long journey to the country of the Hurons, p. 117. The Champlain Society, Toronto, 1939.

Furthermore, as now at Grand River, the patient was also led around in the medicine dance and encouraged to recover, and there was a terminal feast for invited guests.

While these descriptions do not fit the modern ceremonies precisely, they at least contain the kernels out of which the modern rituals have grown.

For the Iroquois of New York at this period we do not find accounts of face painting and masking, comparing the Indians with the masqueraders in the French Mardi Gras. However, the author of Van Curler's journal, whose party visited the Mohawk villages and the Oneida town at Christmas of 1634, tells us how on two occasions the Chief of the first Mohawk Castle ". . . showed me his idol; it was a head with the teeth sticking out; it was dressed in a red cloth."[24] This is reminiscent of the modern custom of covering masks when putting them away. A fortnight later at Oneida, he saw a dozen red-faced Oneida shamans handle and eat fire while attempting to drive away evil spirits to the accompaniment of a turtle rattle.

The "Relations" for 1636 and 1637 mention the antics of the False-faces and their husk-face doorkeepers among the Huron. Brebeuf[25] writes, that in the Midwinter Festival of 1636:

> You would have seen some with a sack on the head, pierced only for the eyes; others were stuffed with straw around the middle, to imitate a pregnant woman. Several were naked as the hand . . .

And so do the modern maskers go naked to the waist. The following December at the great Huron village of Ossosané ". . . they donned their masks and danced, to drive away the disease."[26] During this winter a clairvoyant came into prominence among the Hurons, and his name Tsondacoüanné is not only preserved to us in the "Relations," but my informants identify it with their term for the individual who sponsors a medicine feast (godę̨soni—she sponsored the ritual; sadę̨soni—you . . . sponsor). In a dance which he ordered [to drive away pestilence—

> All the dancers were disguised as hunchbacks, with wooden masks which were altogether ridiculous, and each had a stick in his hand. An excellent medicine, forsooth! At the end of the dance, at the command of the sorcerer Tsondacoüane all these masks were hung at the end of poles, and placed over every cabin, with the straw men at the doors, to frighten the malady . . . [p. 263].

And a day or so later they beat upon pieces of bark, making a great din, and a householder burned tobacco and urged the masks to keep

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[24] Wilson, James Grant, Arent Van Curler and his journal. Ann. Rep. Amer. Hist. Assoc. for 1895, pp. 88, 95, 1896.

[25] Jesuit Relations (Thwaites edition), vol. 10, p. 203.

[26] Op cit., vol. 13, p. 175.

a good watch over his door (p. 267). Another time all the houses in the environs of a neighboring town were decked out with wooden masks and straw figures within 48 hours of the sorcerer's edict (p. 231).

Surely, if these practices had been current among the Five Nations of New York at this time, the Jesuits who visited them during the next few decades would have mentioned the masked ceremonies which they knew from Huronia. Instead, Dablon and Chaumonot, who witnessed the Midwinter Festival at Onondaga during 1656, are silent about masks but describe their host, covering himself with corn husks from head to foot, who went accompanied by two women with blackened faces and bodies covered with wolf skins. Each woman carried a club or a great stake.[27] Beschefer, who accompanied De Nonville's expedition against the Seneca, wrote in the "Relations" of 1687 to Villermont:

> I was mistaken when I told you that the Iroquois wore no masks. They make some very hideous ones with pieces of wood, which they carve according to their fancy. When our people burned the villages of the Tsonnontouans (Seneca), a young man made every effort in his power to get one that an outaouae (Ottawa) had found in a cabin, but the latter would not part with it. It was a foot and a half long, and wide in proportion; 2 pieces of a kettle, very neatly fitted to it, and pierced with a small hole in the center, represented the eyes.[28]

Beauchamp holds that since the Seneca had one Huron town after 1648, the Huron may have introduced the False-face Society to the Seneca, from whence it spread through the other nations of the Confederacy. Lafitau, who bolstered his Mohawk observation with the earlier "Jesuit Relations," says masks were made from the bark of trees.[29] John Bartram, the Philadelphia naturalist, recorded an unmistakable description of a False-face beggar who kept him awake at Onondaga in 1743.

> . . . we were entertained by a comical fellow, disguised in as odd a dress as Indian folly could invent; he had on a clumsy vizard of wood colour'd black, with a nose 4 or 5 inches long, a grinning mouth set awry, furnish'd with long teeth, round the eyes circles of bright brass, surrounded by a larger circle of white paint, from his forehead hung long tresses of buffaloes hair, and from the catch part of his head ropes made of the plaited husks of Indian corn; I can not recollect the whole of his dress, but that it was equally uncouth: he carried in one hand a long staff, in the other a calabash with small stones in it, for a rattle, and this he rubbed up and down his staff; he would sometimes hold up his head and make a hideous noise like the braying of an ass; . . . In my whim I saw a vizard of this kind hang by the side of one of their cabins to another town.[30]

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[27] Op. cit., vol. 42, p. 154.

[28] Op. cit., vol. 63, p. 289.

[29] Lafitau, P. F., Moeurs des sauvages Amêriquains, vol. 1, p. 368. Paris, 1724.

[30] Bartram, John, Observations on the inhabitants, climate, soil, rivers, productions, animals . . . in Travels from Pennsilvania (sic) to Onondaga, Oswego and Lake Ontario, p. 43. London, 1751 (reprinted at Geneva, N. Y., 1895).

Probably a custom as widespread over the world as dressing in masks to impersonate other beings permits us to assume that the Iroquoian custom of wearing false faces sprang from their own or Huron culture whence it spread to the Iroquois after 1648, where it became so firmly imbedded that, despite 300 years of buffeting by white contact, the masks have maintained standards prescribed in the origin legends. The masks show little fundamental change from generation to generation, except that they become increasingly ornate and grotesque when influenced by the adoption of better tools or the degeneration of the wood-carver's art; and masks portraying a pig, the devil, and such amusing figures as Mickey Mouse, Felix Cat, and Charlie Chaplin have encroached only on the group of faces designed to elicit laughter—the class of beggar masks—which is the most plastic.

THE SOCIETY OF HUSK FACES OR BUSHY-HEADS

The Husk Faces are a race of agriculturists. They dwell on the other side of the earth in a ravine where they till their fields amid high stumps. Coming from the east every new year, they visit the Seneca longhouses during 2 nights of the Midwinter Festival. Preceded by runners, they finally arrive amid a great din of beating the building with staves, stop the dances, and kidnap a chief for interpreter. As messengers of the three sisters—corn, beans, and squash—our life supporters, they have great powers of prophecy. The interpreter relates the message of the old woman, their leader, that they are hurrying westward to hoe their crops. In fields about their houses they grow huge squashes; the corn has giant ears, and string beans climb up poles to heaven. Some of their women have remained home to tend to crying babies. Recently in their country there is employment on public works projects. These statements are accepted as an augury of fertility. They request the privilege of dancing with the people. All their company may be men, but some dress as women and participate in the dances as if they were women.

The Husk Face Society is by no means as well integrated or prominent as the False-face Society, although they share certain functions. Unlike the False-faces, they are mutes and only puff as they run with great leaps. They have their own tobacco invocation, a medicine song, and they dance about the staves which they carry. They also have the power to cure by blowing hot ashes; but in Canada they sprinkle water on their patients. They like tobacco, but they prefer popcorn at Allegany and dumplings at Newtown and Tonawanda, instead of mush. When four suddenly appear racing between the houses, they may be signaling the approach of the False-face Company. They will loiter, policing the premises until the Common Faces depart. Relatively few Indians belong to their society, and

set a kettle down for them to renew an old dream, but many put on their masks for the public longhouse rituals, and others join them in social dances at the end of the line.

Origin of the Onondaga Husk Faces.—Hadji'ʻsă (for Gaji'ʻsă'), the Man-being of the Corn Husk Likeness [Mask]—a Tradition of the Olden Time.[31]

(It is said) that in ancient times it thus happened that a man who was hunting in the forest saw there while on the hunt something. He was surprised to see there a deer standing at the bottom of a valley. He killed it. When he had completed dressing the carcass he looked as he turned around and saw standing there nearby a male Husk Face and he asked him, saying, "Where do you come from?" He replied, "From the place where the uprooted tree trunk is."

Again the hunter asked, "Where then are you going?" He answered, "Only thy person too do I come seeking. I am bearing corn. Expressly for thee[you] am I bringing it." He had brought two ears of corn. The hunter then asked, "From what place do you bring it?" He replied, "On the farther side of the bushes one has planted it. Odɛndonni''aʻ (The Sapling or Sprout: a name for the Life God or the Master of Life) has planted that.

"He planted it for you (human beings). It belongs to you (people). I have come bringing it for thee. You must mix it with what you are hunting, when you do eat.

"He himself, gaende'ʻsǫʻk (Moving Winds) sent me from there, and also Otcgǫwɛndet'ʻha' (The Tempest)." He said, "You go deliver the corn. The hunter will carry it back to the people when he returns home! That is the reason I deliver it to you. You must take it home.

"Whole Face Man-being (gaende'ʻsǫʻk), accompanied me. Customarily, I go there [about the houses] when again as usual [whenever] the humpbacked man beings (hoñdu''i') again go about from place to place.

"I have my dwelling place where berries are wont to grow. There in that place usually I pick up corn bread, when [once more] you human beings are gathering berries again. Ordinarily, I take the corn bread which is brought there as provisions. But you [people] never see me.

"Understand that I have dwelt on the earth from the beginning with the Master of Life. I am independent (wild). You must tell your people that you and they must prepare something with corn husks which shall be a likeness of the form of my body. And it shall be that when they wear this husk mask that wearing the mask will enable me to aid them. Understand that it is I who will bring to you [people] all the seeds which you will plant—seed corn, seed beans, and squash seed. All the various kinds of seeds will I deliver in full. I will bring them from the many planted fields of the Sapling (or Sprout—Odɛñdoñni'aʻ—a name for the Master of Life). So then don't let anyone complain of the amount of the seeds which I shall bring (to maturity). Understand also that it is Diyos'a''diʻ (i. e., Producer of all Things), the Mother of the Sprout, who brought them here for us to gather.

"Therefore, appropriately (customarily) when one will have thoughts concerning me than one shall usually say 'Djohgwe''yani' Hadji'ša' (Mr. Partridge Bushy-head).'

"So now you alone must carry home with you all the things which I have given you."

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[31] The native Onondaga-Iroquoian text was dictated June 1916 by Joshua Buck, a Tutelo-Onondaga, of the Six Nations Grant on the Grand River, Ontario, and later revised and translated with notes by J. N. B. Hewitt.

Longnose, who kidnaps naughty children.—The Iroquois and their Algonquin neighbors use buckskin masks to impersonate cannibal clowns who sometimes kidnap naughty children. The Seneca call this clown "Longnose" (hagónde·s) because of his elongated proboscis. He is the Indian bogeyman. He chases bad children when the old people are sleeping. He mimics them, crying out as he runs after them. But the old folks do not wake up, since he has bewitched them in order that they will remain sleeping. This goes on all night until the child gives up and agrees to behave, or else Longnose makes away with the child, carrying him off in a huge pack basket. It is not right to whip little children. Stubborn children who will not go to bed are sometimes sent out at dusk to meet Longnose, impersonated by a relative wearing a cloth mask. The child immediately runs into the house. Neither is it right to use the great wooden masks belonging to the medicine society for scaring little children. The great Faces are sacred and should not be ridiculed; and the being they represent might, through the mask, "poison" the child, or "spoil his face" and bring bad luck to the wearer.

The Bigheads.—At the Seneca Midwinter Festival, two women dress two men in buffalo robes, which they bind with ropes of braided corn husks, from which the ears have been successively pulled for consumption; they hand the men wooden corn pounders and dispatch them about the village. These heralds impersonate the "Uncles" or "Bigheads" who run through the fires heralding the Feast of Dreams which marks the new year. Their costume symbolizes the union of trophies of the hunt and fruit of the harvest. The Bigheads should not be confused with the wooden False-faces or the Husk Faces, who form two distinct but somewhat linked medicine companies.

THE SOCIETY OF FACES, OR THE FALSE-FACE COMPANY

The origin of the False-faces.—Among the Iroquois there are two prevailing types of origin legends for the wooden False-faces. One is a mythical epic belonging to the creation; the other is a human adventure. Both are associated with different classes of beings. In abridged form, here is what Chauncey Johnny John and Henry Redeye heard from their "old folks."

THE STRUGGLE FOR CONTROL OF THE EARTH

Now when our maker was finishing this earth, he went walking around inspecting it and banishing all evil spirits from his premises. He divested the Stonecoats and banished them as harmful to men. He removed the Little Folk's stone shirts and permitted them to remain to help hunters and cure illness. As the creator went on his way westward, on the rim of the world, he met a huge fellow—the head man of all the Faces. The creator asked the stranger, as he had asked the others, whence he came. The stranger replied that he came from the Rocky Mountains to the west and that he had been living on this earth since he made it. They argued as to whose earth they traversed and agreed to settle

the title by contest. The creator agreed to call the stranger "headman," should he demonstrate sufficient magic strength to summon a distant mountain toward them. They sat down facing the east with their backs to the west and held their breath. Now the great False-face shook his giant turtle rattle and the uproar freightened the game animals. He summoned the mountain toward them, but it moved only part way. Now it was the creator's turn, and he summoned the mountain, which came directly up to them. However, his rival, becoming impatient, suddenly looked around, and the mountain struck his face. The impact broke his nose bridge, and pain distorted his mouth. Now the creator realized that this fellow had great power. He assigned him the task of driving disease from the earth and assisting the people who were about to travel to and fro hunting. The loser agreed that if humans make portrait masks of him, call him grandfather, make tobacco offerings, and set down a kettle of mush, that they too shall have the power to cure disease by blowing hot ashes. The creator gave him a place to dwell in the rocky hills to the west near the rim of the earth, and he agreed to come in whichever direction the people summon him.

The Good Hunter's Adventure

Later, as humans went about the earth, in the fall men went into the woods hunting. They carried native tobacco and parched corn meal for mush. They were tormented by shy, querulous beings who flitted timidly behind trees with their long hair snapping in the wind. Sometimes a hunter returned to his camp to find the ashes of his fire strewn about the hearth and the marks of some great, dirty hand where someone had grasped a house post for support as he leaned over and pawed in the fire. The hunter agreed to stay home while his partner went afield. During the morning, a False-face approached cautiously, sledging on one hip, now and then standing erect to gaze about before proceeding. Going to the hearth, he reached into the ashes and scattered the coals as if seeking something. That night the hunter had a dream in which the False-face requested tobacco and mush. The next day, the hunter set a kettle down for them. The Faces came and taught him their songs and their method of treating patients with hot ashes. In a subsequent dream, they requested him to remember them every year with a feast, saying they are everywhere in the forests, bringing luck to those who remember them.

Another legend from Chauncey Johnny John tells of a hunter who inadvisedly shot but failed to kill an old man whom he discovered sitting on a log in the forest. The man returned the arrow, instructed the hunter to make 100 bark bowls, to cook a great kettle of mush, and provide tobacco for a company of 100 who would appear next day. The amazed hunter fulfilled everything, and when he was ready, Faces of all ages gathered around his fire. The old man, who was their leader, taught him a tobacco invocation and three songs. They showed him how to cure by blowing hot ashes, and presented him with a miniature mask to serve as a model for making larger ones.

Hunters returned home to their villages. They related their strange adventures and revealed their dreams. Sometimes after returning home, they had new dreams and received further instructions. They showed their people how to make masks and they organized a medicine company.

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THE CLASSES OF MEDICINE MASKS

Rationalizing from the two types of origin legends, the modern Iroquois conceive two main classes of False-faces: First, their leader, the great fellow who lived on the rim of the earth, and secondly, his underlings, the common forest people whose faces are against the trees. The great one, called shagodyowéhgo·wa· [hadjá'dot'a', "Our defender the doctor," in Seneca, and "The great humpbacked one (hadu''i'go·na')" by the Onondaga, is the greatest doctor. He is earth-bound and traverses the earth from east to west following the path of the sun. He is tall and carries a great staff, made from a giant pine or shagbark hickory tree with its branches lopped off to the top. He walks with great strides, bumping his cane and shaking the earth. He carries a huge mud-turtle rattle, and he stops at noon to rest and rub his rattle on the giant elm or pine which stand in the center of the earth and from which he derives great strength (pl. 17, fig. 1). His face is red in the morning as he comes from the east, but black in the afternoon as he looks back from the direction of the setting sun. He controls high winds and has a wary eye for pestilences which might destroy the people. He has a song which refers to his power over winds and pestilence. Few have ever seen him. He dances, kicking out his feet and sparring, his thumbs pointed in the air as if he were about to fall over backward. He makes the people imitate him, organizes them in a round dance, and watches the door to see that no one leaves or enters. Masks representing him have long hair. They are painted red or black and portray the broken nose and pain he suffered when the mountain struck his face. A few masks have high-bridged noses, and all have protruding lips, which are twisted with the nose, straight, hanging, or flaring like two funnels or flattened like spoons, for blowing ashes.

The second class are the Common Faces, who live everywhere in the forests (pl. 17, fig. 2). They are deformed, either hunchbacked or crippled below the waist. Some carry rattles, made by folding a rind of hickory bark; a few possess turtle rattles, but others have only a stick. They crave mush and beg for tobacco. They have a dance and a song, and they will cure by blowing hot ashes. Masks of this category are ill-defined and include a great variety. Frequently new masks make their debut with the Common Faces; but after they have been worn in many rituals, borrowed and passed through the hands of several owners, they will have accumulated several bags of tobacco offerings, attained an antique color, and achieved sufficient prestige to graduate into the class of great doctor masks where their sanctity is preserved by reputation.

THREE SOCIETIES EMPLOY MASKS

Among the Iroquois, three distinct medicine societies employ masks. They perform their rituals in public or privately. The False-face Company, who wear the wooden masks, include both orders of medicine masks who have three distinct rituals. Their public rituals are the spring and autumn exorcism of disease from the settlements and cures which are sometimes sponsored in the longhouse during the Midwinter Festival. However, the public appearance of the Beggars and Thieves, during several nights of the midwinter ceremonies, are merely a motely group of boys who sometimes "take sick" afterward and thereby gain admittance to the society (pl. 18, fig. 1). The second ritual belongs to the Common Faces, who enter a house and dance (pls. 19, 20). The Common Faces may be followed by the great, world-rim Faces, whose ritual is the Doorkeeper's Dance. The Society of Faces is the body of people who have been cured by the masked company. The separate society of Husk Faces appears publicly two nights at the Midwinter Festival. They have their own invocation, songs, and a curing dance. Membership is gained by a dream or cure, but nonmembers join in their public dances, dancing at the end of the line. Frequently at Allegany two special Husk Faces appear as doorkeepers for the Common Faces at private curing rites and as heralds and longhouse police during public rituals. Among the Canadian Iroquois, masked societies seem more highly specialized, but at Allegany and Tonawanda their functions are less clearly defined. At Newtown, on Cattaraugus reserve, the Society of Mystic Animals (hadi′′do·s) possess certain "secret masks" of which one has no eye holes, but at Coldspring on Allegany Reservation certain black or white Faces, which are also used as medicine masks by the Society of Faces, appear in one ritual of the Society of Mystic Animals and juggle hot stones or hot ashes while curing the patient (pl. 18, fig. 2).

Membership.—An Iroquois Indian joins a particular medicine society after a dream or because a clairvoyant has prescribed the ritual of that society to cure a sickness. He automatically joins all the societies, and is afterward duty bound to sponsor any combination of rituals that have assisted his recovery. Thus the Society of Faces includes persons who have been cured by the False-face Company. Membership in the several orders of the society, or participation in the rituals of the masked company depend on an individual's personal history. The masked company are men wearing masks of the orders which cured them, but both men and women sponsor the rituals and belong to the orders that have accepted them for membership in the society by making them sick. Among the Seneca, two head women, one from each moiety of four clans, are responsible for certain equip-

ment and manage the rituals. Members of both sexes attend. A member should put up a feast every year for the orders which have helped him. He calls in the head woman of the opposite moiety to conduct the ritual. His membership ceases rarely, when he dreams he has been released. Then he knows he is no longer a member.

THE FALSE-FACE SICKNESS

Symptoms of the False-face sickness are ailments of the head, shoulders, and joints. Masks cause and cure swelling of the face, toothache, inflammation of the eyes, nose bleeding, sore chin, and earache. At Tonawanda, red spots on the patient's face are False-face symptoms. This calls for the red Faces, who should dance in the morning before sunrise. Black spots require the use of black masks at night. Imaginary hair lying on the patient's face, indicated by her attempts to brush it aside, is a False-face symptom. The patient complains to her old people. They consult a clairvoyant, who prescribes a False-face ceremony. To ridicule the masks or any of their ceremonies is inviting sickness or misfortune.

Cases of hysterical possession formerly occurred among Iroquois women. A Tonawanda informant states that it was confined to certain nervous women who became possessed of the False-face spirits whenever the masked men appeared (Peter W. Doctor). On hearing the rumpus of whining and rattles, which marks their approach, one woman would fall into spasms, imitate their cry and crawl toward the fire, and, unless she was restrained, plunge her hands into the glowing embers and scatter the fire as if she were a False-face hunting tobacco. Some one always grabbed her, while another burned tobacco, imploring the masked men to cure her. The ritual usually restored her normal composure. Other women became possessed of the tutelaries of the Bear or Buffalo societies. My informant used to think women became possessed to show off. Some of these women were clairvoyants. Another informant remembers a man who became possessed 30 years ago at Newtown, for resisting a doorkeeper (Jesse J. Cornplanter). When the masked ritual conductor nudged him with his rattle, he obstinately refused to join the round dance. They struggled and the man, overcome with fear, fell into a spasm and cried like a False-face. They had to blow ashes on him. Afterward, the man did not remember his behavior. In all cases, the form of the hysteria was prescribed by the culture. These cases resemble those which Champlain and the missionaries witnessed at Huronia. The Feast of Fools of the early Hurons has evolved from a random series of hysterical dream fulfillments to an organized Midwinter Festival by a gradual standardization of forms differing according to locality.

THE MASK AND RATTLE

Men belonging to the Society of Faces usually own a bundle containing a turtle rattle and one or more masks decorated with bags of sacred tobacco. When not being used, the mask is laid away, face down with its hair wreathed around the face and the turtle shell placed in the hollow at the back of the mask; and the whole is wrapped in the cloth head cover. Sometimes unwrapped masks are hung upstairs, but facing the wall. A mask hung facing out should be covered, lest some frightened persons become possessed and join the society. One must be careful of them. If a mask falls, the owner burns a tobacco offering and ties a little bundle of sacred tobacco at the ear or forehead. Whenever he dreams about the Face, he will rise and repeat the ritual. Every man has a package of tobacco on his mask which he removes when he sells it to white people. He burns tobacco, telling the mask that it is going away. He asks it not to return and harm him or the new owner (pl. 21, fig. 2). Everyone belonging to the society may use anyone else's face. A new owner will add a package of tobacco to a mask, and if he purchases one already having several attached medicine bundles, he adds his own; but a maker does not tie tobacco on a mask unless he intends to keep and use it. Sometimes the masks become hungry and the owners rub their lips with mush and anoint their faces with sunflower oil, which after many years imparts a rich luster. A man, having no children, may request that a mask be buried with him.

Unless the new member inherits an old mask, he must carve one or enlist the services of a carver. They say at Tonawanda that softer woods are best for carving masks. Basswood has the prestige of tradition, but other soft woods like willow and cucumber are also used. Anciently, a man went into the forest to carve his masks. He carried native tobacco and sought a living basswood tree. Now he committed the tobacco to the burning embers, a pinch at a time, addressing his prayer to the tree and the beings whom the False-faces represent. Then he carved the face on the living tree (pl. 21, fig. 1), and having roughed it out, he notched the tree with an ax above the forehead and below the chin and cleaved away his sculpture in a solid block. It is said that the carving never broke because one had put tobacco and asked the tree for its life. Nor did the tree die. Within 4 years, the scar healed over. He took home his block, covered it and worked on it at his leisure. When the features were finished, he hollowed out the inside (with a bent farrier's knife), and perforated the eyes, nose, and mouth (pl. 22). He encircled the eyes with metal, for the Great False-face's eyes are bright. Then he painted it. If he had sought his tree in the morning, he painted the

mask red; but if he found the tree and commenced carving after noon, the mask would be black. This color symbolism originates with the theory of morning and afternoon appearance of the giant, world-rim resident. During his daily westward journey following the path of the sun, his face would appear red in the morning and dark in the afternoon when the sun is behind him. For the long hair which falls on either side to his knees, the mask maker attaches to the forehead horsetails, tanned with deer brains.

RITUAL EQUIPMENT

The False-face Company carry wooden staves and employ three instruments: The typical mud-turtle rattle, a folded bark rattle, or a billet of wood. On late spring evenings, before summer heat peels the turtle's shell, Indians watch for turtles about the ponds and creeks. In the evening one may meet an Indian bearing a burlap sack containing a turtle, or he carries it by the tail; he is bound to the house of a friend who "can fix it" for a rattle. The rattle maker cuts off the turtle's tail or severs the jugular vein and hangs it to drain. Later, he eviscerates and cures it. He sews up the apertures left by removing the rear limbs and inserts a handful of cherry pits. He stretches the neck over a pine stick which extends from inside the shell to the base of the skull where it is notched. He sews the front rents. Cutting three hickory splints, he inserts one in the sternum, cutting it off under the jaw, and he inserts two lateral splints in the back of the shell, terminating them on top of the head. He binds the splints to the neck with basswood fiber, a withe of inner elm bark, or rawhide, commencing at the shell and whipping toward the head. A ten-inch rattle is best for singing, but the mammoth turtle rattles lend awe to the doorkeepers at curing rites and small turtle rattles furnish comedy for little boys playing beggars (pl. 23, fig. 1).

For the bark rattles, a cylinder of green hickory bark is slit longitudinally and peeled around the tree. The maker spreads it at the middle by inserting his thumbs and folds it end to end, placing one curled end inside the other (pl. 23, fig. 2). A few cherry pits, pebbles, or kernels of corn provide the necessary percussion. He plugs the open end with a corncob and lashes it with a bark withe. A man will make a dozen on a summer afternoon and toss them overhead in the loft to dry.

At next Midwinter Festival, a band of outlandishly dressed little boys wearing beggar masks may visit him soliciting or pilfering food and tobacco for a feast. He will reward them, and then, reaching overhead, distribute his rattles to those poor youngsters who were unable to locate turtle rattles and carry sticks of kindling. Perhaps

he has no children of his own. He will sing for them and they will dance and depart.

A rattle borrowed from a dancer or a stick of wood is good enough to beat time for the dances. But despite the Indians' ingenuity to makeshift of anything at hand the False-face Company sometimes possess dance-tempo beaters. They range in design from wooden cudgels to elaborately carved wooden turtles that have been hollowed to house noisy pebbles. These wooden replicas of the genuine turtle rattles exemplify the transfer to an artistic medium of a design originating with a structural invention.

Miniature masks.—Boys sometimes learn by carving miniature masks. The mask may make the owner ill and then he joins the society. Masquettes are also charms to protect dwellings against witchcraft, or they hang on larger masks. A man may carve one in response to a dream and carry it for good luck. At Cattaraugus, the leader of the society carries a striped pole on which a tobacco basket, a small wooden face, a tiny husk face and a diminutive mud-turtle rattle hang near the top. This is her staff of office when she leads the masked company from house to house exorcising plagues.

Spring and autumn house cleaning.—In the spring and fall, when sickness lingers in the settlements, a great company, wearing both classes of medicine masks, go through the houses frightening disease spirits. At Coldspring, two groups start at opposite sides of the settlement. They are preceded by Husk Face runners. Members take down their masks and rattles and join the procession as it passes. The masked exterminators frequently strip to the waist and go armed with rattles to scare the spirit of sickness and carry pine boughs to brush away malefic influences. A believer is said to suffer no injury from plunging his bare hands into the fire nor become sick from exposure while traveling in cold weather. One winter at Allegany the company afforded a wild spectacle as they sped up the valley road in open Fords with their hair whipping in the chill winds; they grated their rattles on the car body and uttered their terrifying cries whenever they swerved to pass a stranger. Approaching houses occupied by members of the society, an unmasked leader sings:

A long voice, A long voice
yowige yowige wige

and on again entering the longhouse:

It might happen, It might happen
ha i ge ha i
From the mighty Shagodyoweh
ha i ge he i
I shall derive good luck
ha i ge he i

He hopes that the great one dwelling on the rim of the earth will confer his power on the masked company and prevent high winds from leveling the settlement. They scour the exterior of the house and, crawling through the door, visit every room. They sweep beneath the beds and peer into every nook and corner for disease spirits. They haul the sick out of bed and sometimes commit indignities on lazy people. If someone has set a kettle down for them, their leader will burn tobacco, and ask the masked company to blow ashes on the patient. Their only fee is native tobacco, which their guide collects in a twined husk basket. Once at Newtown, a leader was about to gather his company of exterminators and depart for another house when one turned up missing. They heard a most terrifying racket in the loft. They ascended to discover him violently shaking an old straw bedticking, from which bedbugs were fleeing by the score. This fellow, now an old man, possessed of an extraordinary sense of the ridiculous, was shaking his rattle and crying in the most orthodox manner. It is a good example of the frivolity which may pervade an otherwise serious ritual.

Meanwhile, the two matrons brew a purgative at the village cook house. At Newtown and Tonawanda, the sole ingredient is parched white sunflower seeds, which are steeped for the medicine, but at Allegany they add "manroot" (*Ipomoea pandurata*), which must be found growing erect like a living person.

The community assembles at the longhouse. An appointed speaker returns thanks to all the spirit forces. At Coldspring, Husk Face runners and the marching song signify the approach of the combined company. Bursting into the room, the False-faces crawl toward the fire. Each matron entrusts a pail of medicine to one of them whom she designates "water waiter" for her moiety. Lest they scatter the fire about the room, an appointed priest makes an invocation, burning the tobacco that was levied at the houses. He implores them to protect the people against epidemics and tornadoes.

Tobacco Invocation

Partake of this sacred tobacco, O mighty shagodyoweh, you who live at the rim of the earth, who stand towering, you who travel everywhere on the earth caring for the people.

And you too, whose faces are against the trees in the forests, whom we call the company of faces; you also receive tobacco.

And you Husk Faces partake of the tobacco. For you have been continually associated with the False-faces. You too have done your duty.

Partake of this tobacco together. Everyone here believes that you have chosen him for your society.

So now your mud-turtle rattle receives tobacco. (Here they scrape their rattles on the floor.)

And now another thing receives tobacco, your staff, a tall pine with the branches lopped off to the top.

So presently you will stand up (they crawl in) and help your grandchildren, since they have fulfilled your desires. Fittingly, they have set down a full kettle of mush for you. It is greased with bear fat. Now another thing is fulfilled: on top there are strips of fried meat as large as your feet. (Here the False-faces roll in ecstacy on their backs, grasping their feet, peering at them, and attempting to put them in their mouths.) Besides, a brimming kettle of hulled-corn soup rests here.

Now it is up to you. Arise and help your grandchildren. They have fulfilled everything that you requested should be done here. In my opinion we have these ashes here for you to use. Arise and make medicine.

Here the priest summons those who wish to be cured to come forward and stand near the fire to receive the administrations of the False-faces.

The masked waiters pass the medicine water. Every one drinks all he can. Two Husk Faces watch the doors to insure that no one leaves or enters during the imbibing. However, they can sometimes be bribed with a pinch of tobacco.

There are dances for each class of Faces. An appointed singer straddles a bench, and borrowing a rattle, sings for the Common Faces alone. They stand up and dance and apply hot ashes to any patients whose dreams have required that they be cured on this occasion. Frequently, little boys who are wearing masks have to be held up by their elders in order to blow ashes on the patients' heads. Sometimes, a clever little fellow will puff the ashes at the patient from his upturned hand. At Tonawanda, the masked dancers cure each other. A matron distributes tobacco and they depart with their kettle of mush.

Next the Husk Faces perform, receive popcorn, and bound out of the room.

The second part of the ritual, named "They place one foot ahead of the other" for one of its component dances, includes the Dance of the Doorkeepers. The song commences. Two men, who are appointed from opposite moieties, appear wearing the medicine masks representing the great world-rim beings. They dance with the matrons, each facing the woman of the other moiety. A couple dances in unison, hopping on the left foot while bending the right knee and then kicking out the right foot. At the same time they spar at each other with the extended left hand, pointing the thumb upward. The turtle rattles dangle by the loop on the handle. Now the matrons pair the men and women in couples who dance imitating the False-faces. They spar at each other and a bold woman will sometimes back a bashful man from the floor. A doorkeeper looks inside once during each song (pl. 24).

Then they return and compel everyone inside to join a round dance, from which the ritual takes its name, since a dancer lifts his foot, bumps his heel and sets it down again ahead of the other.

One doorkeeper directs the dance, while his cousin watches the door to see that no one escapes the ritual.

The member who wears the mask to impersonate the doorkeeper is supposed to know the members of the society. You can pick out the members. They look scared. They look at you hard, or they pretend to be busy about some other business of their own. You can discern them through the mask. If any are reluctant to join, you have the power to force them, a strength against which they dare not resist. Sometimes fights occur. If one is not able, his partner, the other doorkeeper, will help him. Members *must* dance. Those who resist become possessed.

The round dance continues until certain songs request them to blow ashes. They repeat their square dance with the two matrons, blow ashes on their heads, receive tobacco, and depart. The feast is hulled-corn soup.

Although I have outlined the great public ritual, the same general pattern holds for private medicinal rites. The only difference is that the priest mentions the person's name in the tobacco invocation. Then the complexity of the ritual depends on the number of orders to which the patient belongs.

The simpler ceremony of the Common Faces alone has been vividly treated by Ernest Smith, a Seneca Indian artist of the Tonawanda reservation (pl. 25).

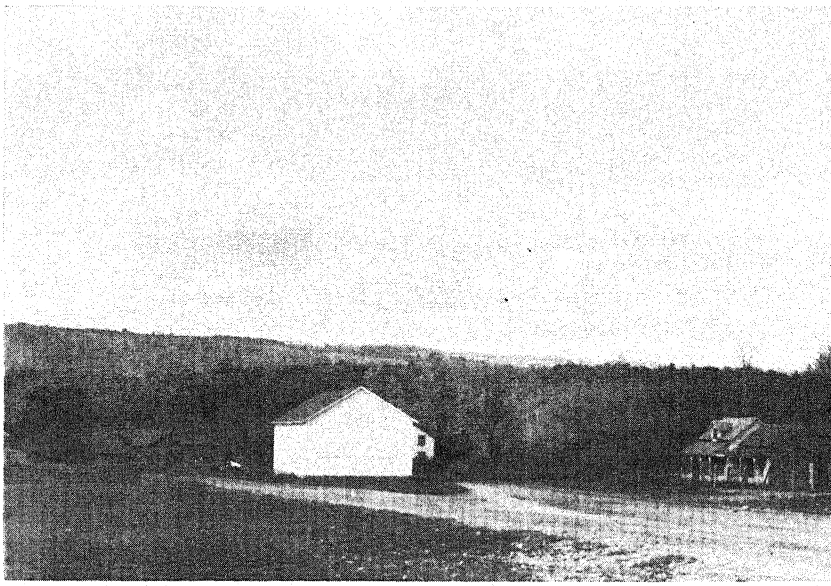
The Blowing Ashes Rite

The setting is the interior of a bark house, common among the Iroquois a few generations ago, and the time is presumably an evening of the Midwinter Festival. In response to a dream, the host has prepared a kettle of mush, or False-face pudding, and summoned the False-faces. The announcer, who is painted sitting on the bench, has returned thanks to all the Spirit-forces, explained the purpose of the feast, and invoked the Faces-of-the-forests with burning tobacco. They have entered. The singer straddles the bench to beat out the tempo for their dance, which they energetically commence, scattering ashes everywhere. They hasten to finish curing the patient, their host who stands before the fire, since they crave tobacco and hunger for the kettle of mush which he has set down for them. A tall, red-faced fellow vigorously rubs the patient's scalp before blowing the hot ashes into the seat of the pain. A dark one moans anxiously while rubbing hot ashes between his palms prior to pouncing on his victim's shoulder and pumping his arm. Across the fire, a red face stoops to scoop live coals, while another impatiently shakes a turtle rattle. They are naked above the waist, but wearing the masks is said to protect their bodies from cold and their hands from the burning embers.

Although the real Faces are seldom seen now, modern Iroquois, especially little children, fear them. A being which has the power to control disease, who can also cause the same ailment which he cures, is a subject for concern. The degree to which the False-faces dominate the lives of the Iroquois is well illustrated in the

testimony of a sophisticated woman of Shawnee and Cayuga parentage whom Dr. Margaret Mead met among the Omaha. The informant had long since removed from her own tribesmen, but her childhood impression remained.

I remember how scared I was of the False-faces; I didn't know what they were. They are to scare away disease. They used to come into the house and up the stairs and I used to hide away under the covers. They even crawled under the bed and they made that awful sound. When I was bad my mother used to say the False-faces would get me. Once, I must have been only 4 or 5, because I was very little when I left Canada, but I remember it so well that when I think of it I can hear that cry now, and I was going along a road from my grandfather's; it was a straight road and I couldn't lose my way, but it was almost dark, and I had to pass through some timber and I heard that cry and that rattle. I ran like a flash of lightning and I can hear it yet.



1. The Longhouse of Handsome Lake's followers in Onondaga Valley near Syracuse.

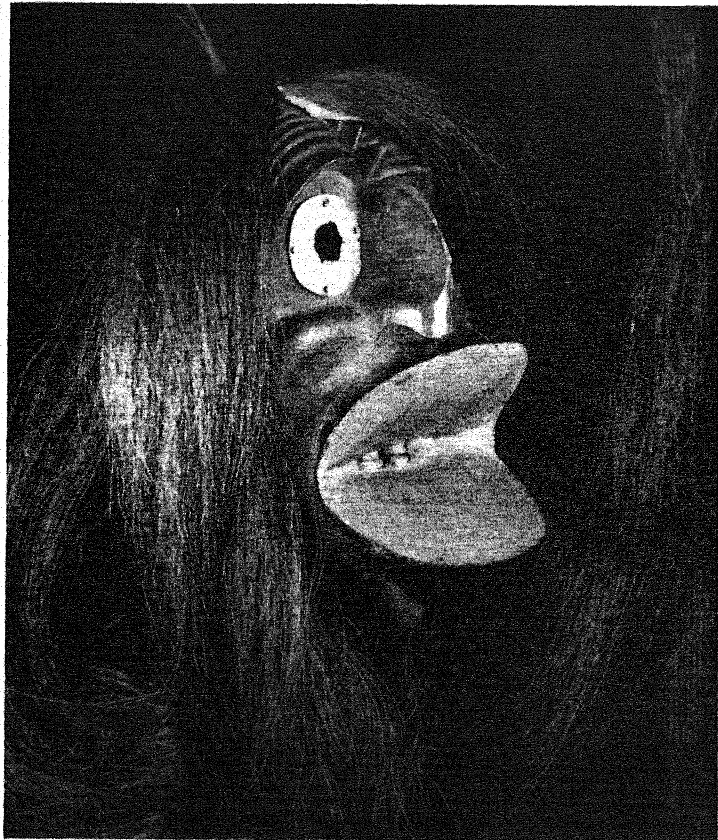
The Longhouse of the Onondagas of Six Nations on Grand River in Southern Ontario, Canada.

LONGHOUSES.

1. Carved by Elijah Hill, of Onandaga Reservation, N. Y. Museum of the American Indian, Heye Foundation, Cat. No. 8775.

2. Black wry-mouth mask characteristic of Iroquois of Grand River. New York State Museum, Cat. No. 37019.

CROOKED-MOUTH MASKS FROM THE ONONDAGA OF NEW YORK AND GRAND RIVER.

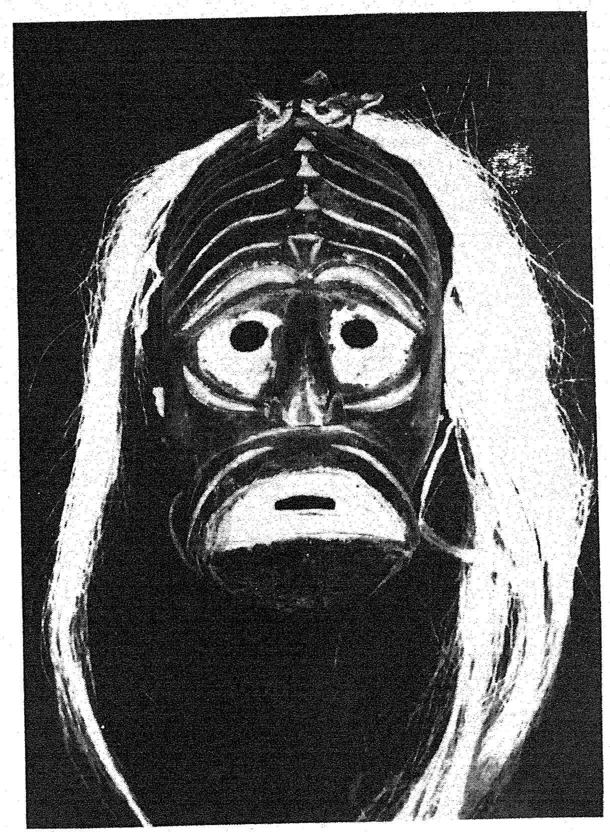


1. Black mask with red lips and spines on forehead. New York State Museum, Cat. No. 37023.

2. Red mask with gray hair. Rochester Museum of Arts and Sciences, Cat. No. AE 7.1.0/404.

STRAIGHT-LIPPED AND SPOON-LIPPED DOORKEEPER MASKS FROM THE SENECAS OF NEWTOWN, CATTARAUGUS RESERVATION, N. Y.

1. An early mask that traveled to Canada ca. 1775. New York State Museum, Cat. No. 37057.



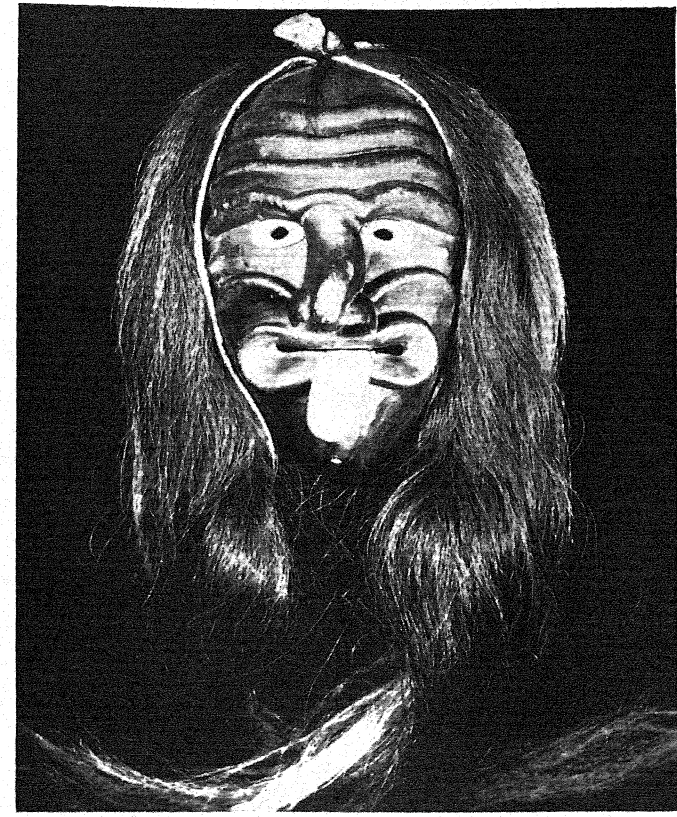
2. An old red doorkeeper mask with white hair. New York State Museum, Cat. No. 37033.

THE HANGING MOUTH, LIKE THE MUSE OF TRAGEDY, IS AN OLD MASK TYPE WITH THE IROQUOIS.

1. Photograph from American Museum of Natural History, New York. Cat. No. 50/7214.

2. Photograph from American Museum of Natural History, New York. Cat. No. 50/7212.

MASKS WITH PROTRUDING TONGUES COLLECTED BY DECOST SMITH AT ONONDAGA CASTLE, N. Y., 1888.



1. Made at Grand River about 1829 by John Styres and collected by David Boyle, 1899. Royal Ontario Museum of Archaeology, Cat. No. 17020.

2. The first Iroquois mask collected by an ethnologist, L. H. Morgan. Onondaga of Grand River, ca. 1850. New York State Museum, Cat. No. 36909.

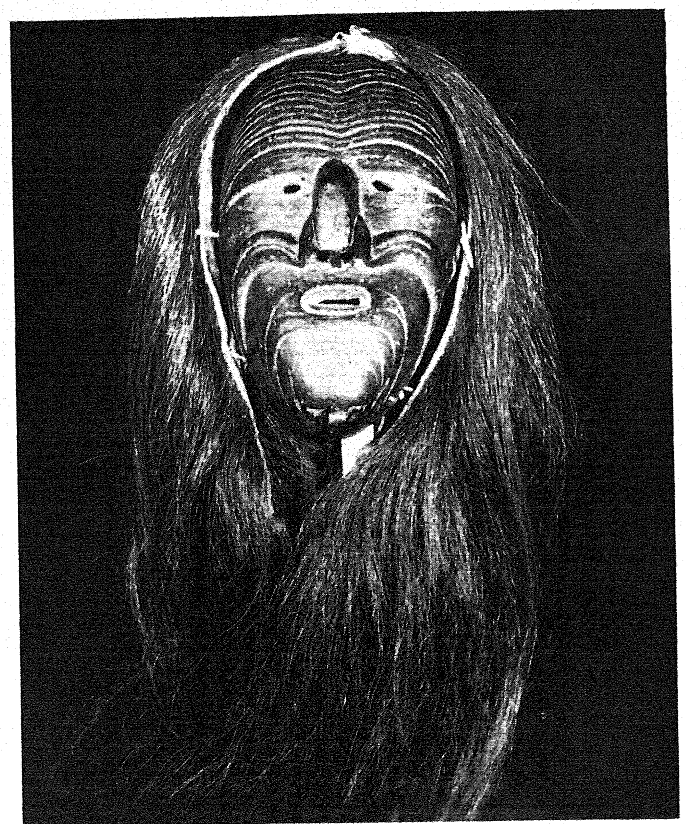
HEAVY CARVING AND A LOLLING TONGUE ARE COMMON FEATURES IN MASKS FROM THE ONONDAGA OF GRAND RIVER.

1. A smiling black beggar mask by Joanas Snow, a Seneca of Coldspring. Museum of the American Indian, Heye Foundation, New York, Cat. No. 20/2839.

2. A heavy mask with thick, smiling lips, from Grand River. Museum of the American Indian, Heye Foundation, New York, Cat. No. 1/2535.

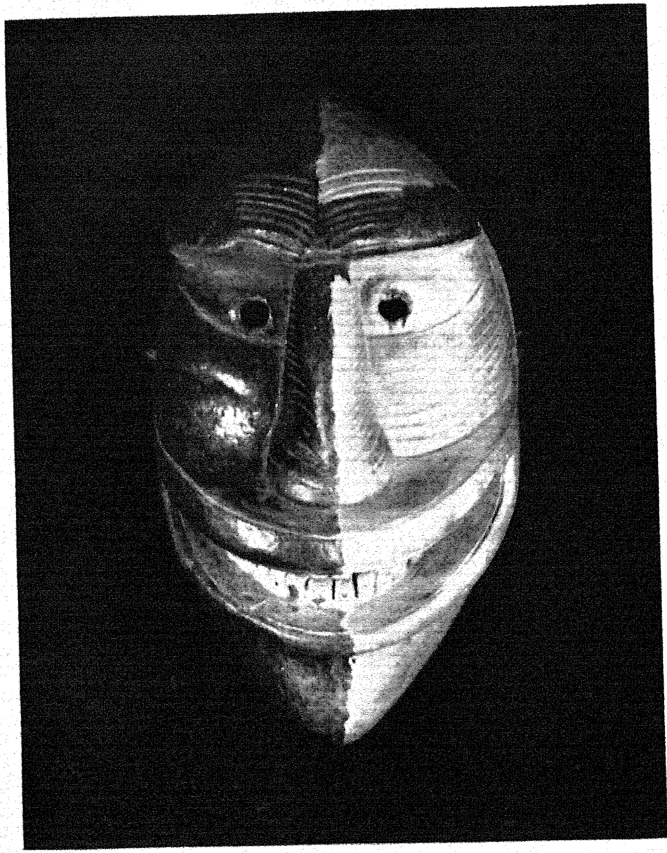
NOT ALL THE MASKS ARE WRY-FACED; SOME ARE SMILING.

1. Red-faced whistler from Tonawanda (?) has a pock-marked forehead and long black hair. New York State Museum, Cat. No. 36867.



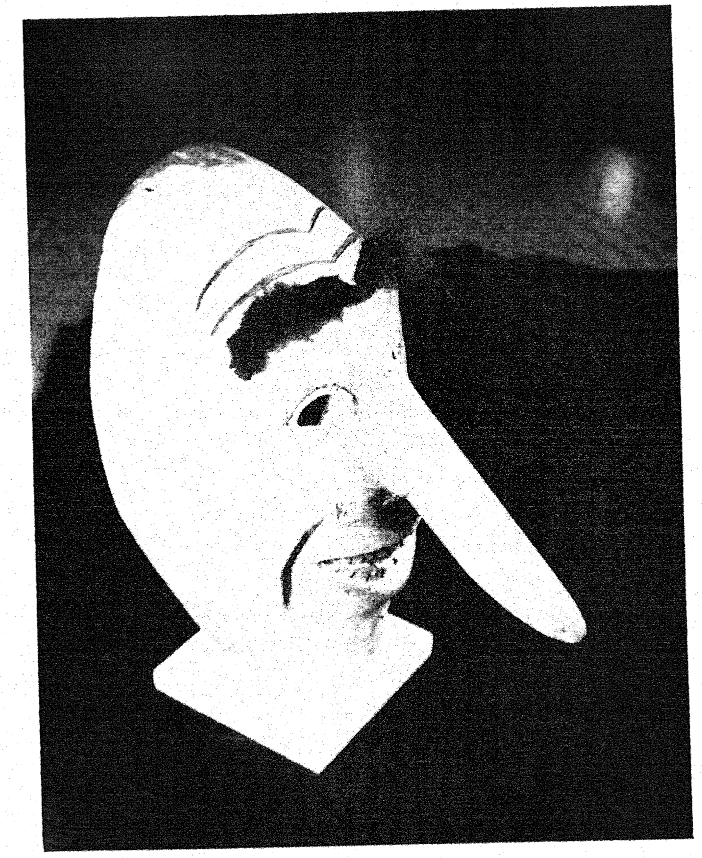
2. A black mask from Grand River; probably a likeness of the Whistling God. Royal Ontario Museum of Archaeology, Cat. No. HD 12634.

THE WHISTLING MASKS ARE LIKENESSES OF FOREST SPIRITS WHO MERELY WANT TOBACCO.



1. He Whose Body Is Riven in Twain.

Divided mask, black and red, in typical Grand River style, by Jake Hess, Cayuga. Royal Ontario Museum of Archaeology.



2. A Long-Nosed Mask Improvised From a Pine Trunk and Branch.

From the Cattaraugus Seneca. Museum of the American Indian, Heye Foundation, Cat. No. 20/1879.

1. A puckish mask by Eli Schenandoah, Onondaga Reservation, N. Y. Collected by M. R. Harrington. Museum of the American Indian, Heye Foundation, Cat. No. 10975.

2. A cloth mask of Longnose made to frighten a naughty child, by Clara Redeye, Seneca, Allegany Reservation. U. S. National Museum.

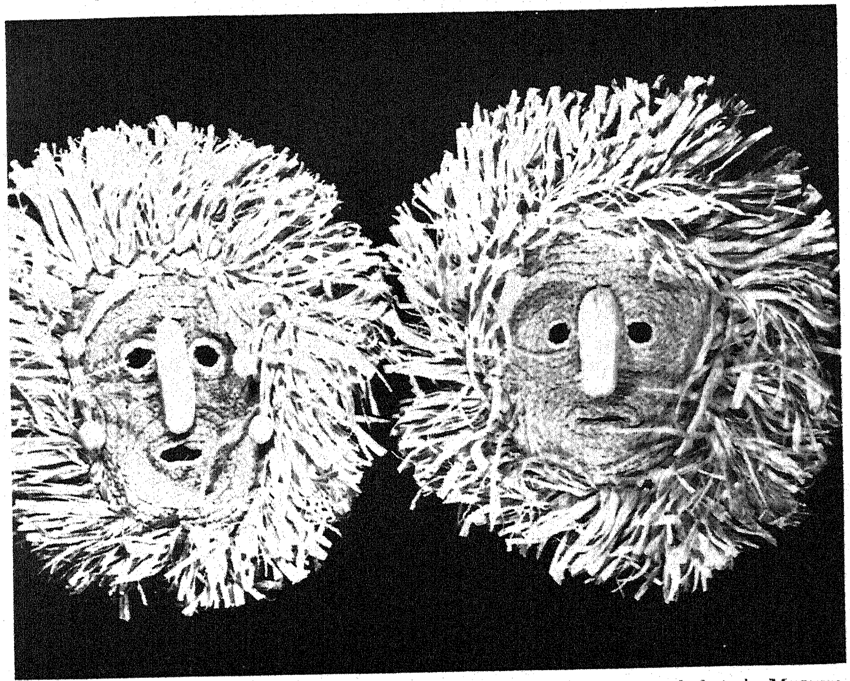
LONGNOSE MASKS ARE CONSIDERED FUNNY.

1. So-called "buffalo" mask of Seneca. Note ears and earrings, present on some masks. New York State Museum, Cat. No. 37608.

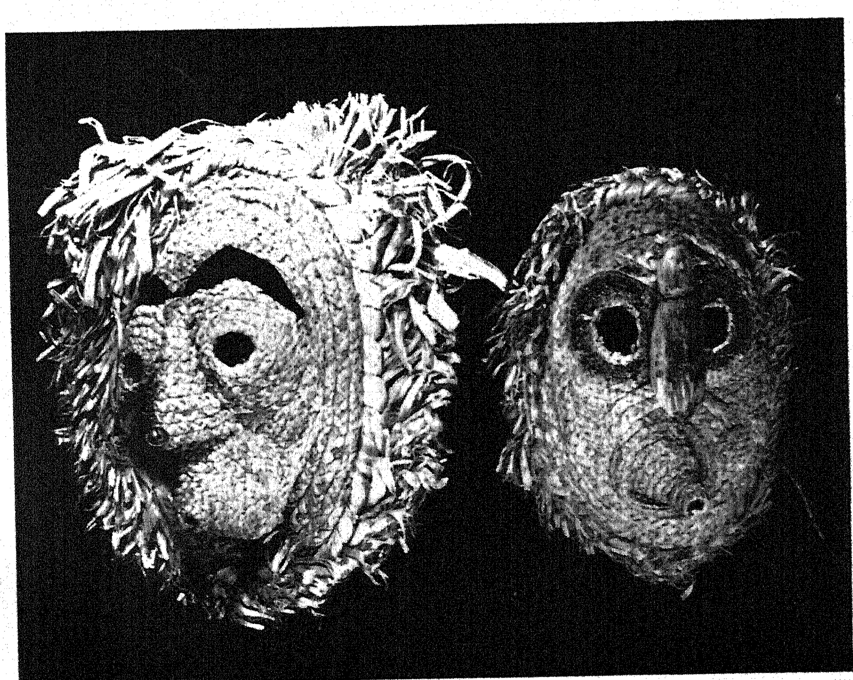
2. Pig mask from Seneca of Cattaraugus. Buffalo Historical Society, Cat. No. 282.

ANIMAL MASKS ARE UNCOMMON AMONG THE IROQUOIS.

I'DOS SOCIETY MASK FROM SENECA OF GRAND RIVER RESERVE, ONTARIO, CANADA.
Museum of the American Indian, Heye Foundation, Cat. No. 6/1105.

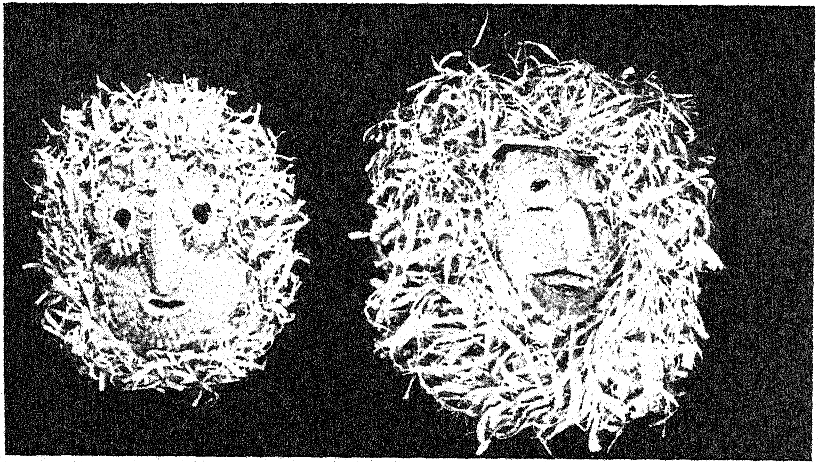


1. Grandmother and grandfather Bushy-head from Cattaraugus Senecas. Royal Ontario Museum of Archaeology, Cat. Nos. HD 8125 and 8126.

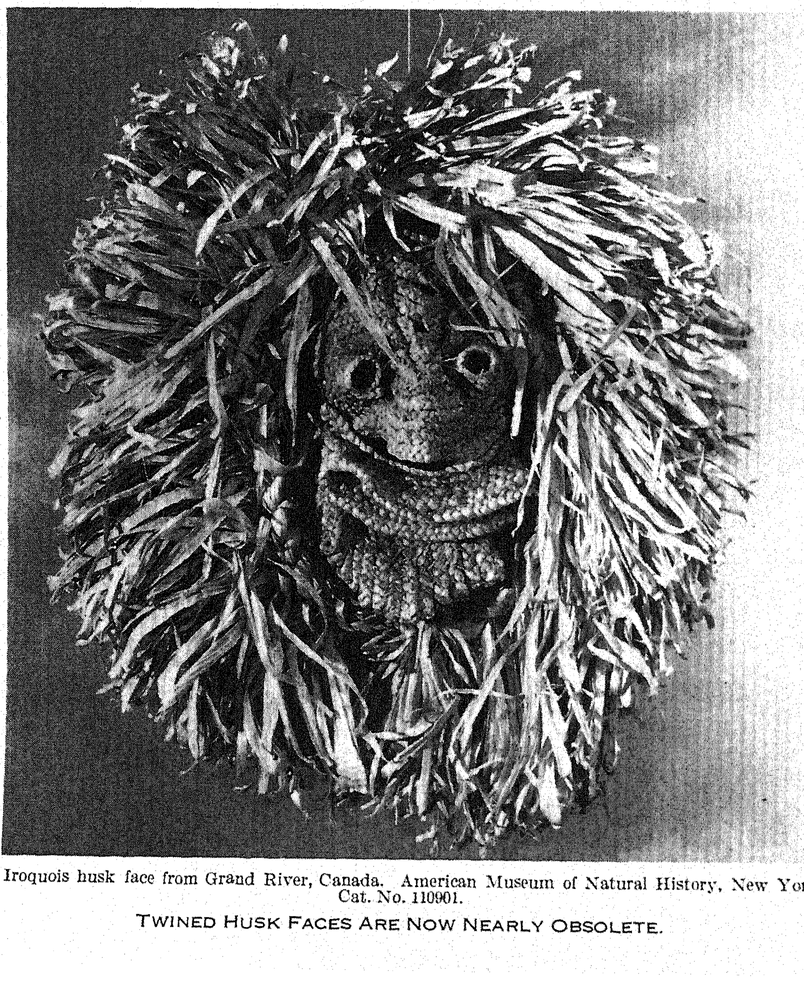


2. The rougher looking ones are old men; usually they have small, round mouths. Laidlaw Collection from Grand River, Royal Ontario Museum of Archaeology, Cat. Nos. 43347 and 21468.

HUSK FACES OR "BUSHY-HEADS" RESEMBLE BRAIDED FOOT MATS.

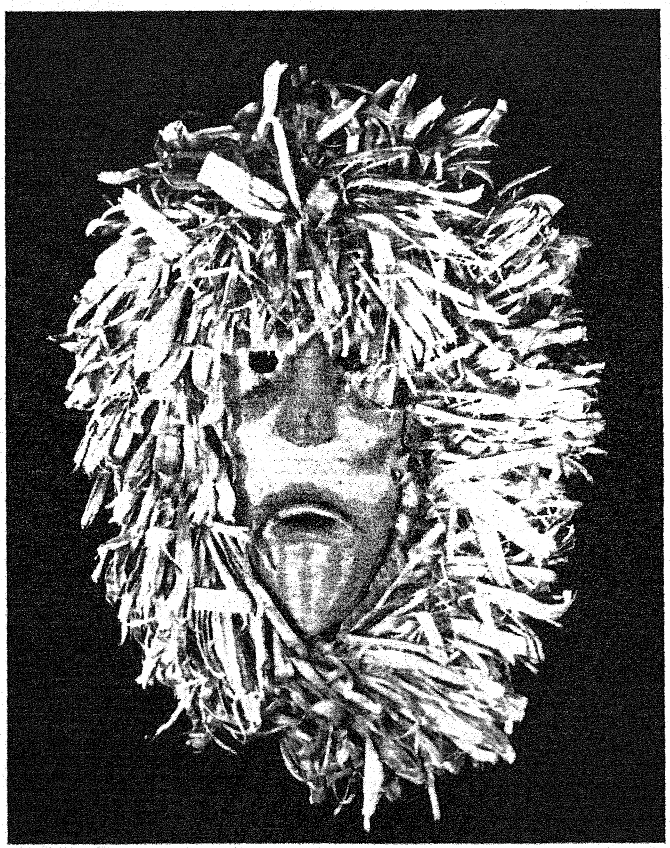


1. Left, twining commences at the mouth or nose; right, a braided bushy-head with puffy cheeks and red mouth. Senecas of Cattaraugus. New York State Museum, Cat. Nos. 36924 and 36922.



2. Iroquois husk face from Grand River, Canada. American Museum of Natural History, New York Cat. No. 110901.

TWINED HUSK FACES ARE NOW NEARLY OBSOLETE.



1. The wooden bushy-head from the Onondaga of Six Nations, Grand River, Canada. New York State Museum, Cat. No. 37018.

2. Miniature personal guardian masks in characteristic art styles. Top, blind masquette from Grand River, with tobacco bag; left and right, spoon-lipped miniatures from Cattaraugus; bottom, Seneca miniature bushy-head. Museum of the American Indian, Heye Foundation, Cat. Nos. 2/4337, 6/1108, 2/9809, 7/9888.

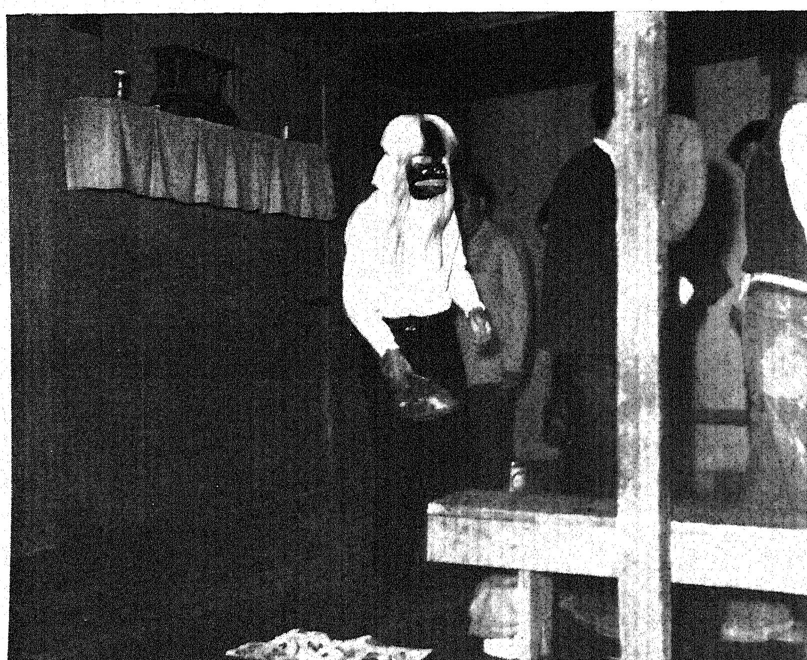
STONE PIPE WITH BLOWING OR WHISTLING SPIRIT MASK FACING THE SMOKER, HAVING EXTENDED NARES, SUPPLEMENTARY WRINKLES AROUND MOUTH AND EYES OF IROQUOIS MASK STYLE.

Side view shows ears, sometimes present on masks, and in rear view one sees head ties or hair braids. Found below Sugar Run, emptying into Allegheny River above Warren, Pa. Courtesy of S. Farver, Palmyra, Pa.

1. Our mighty protector traverses the earth. An Allegheny Seneca employs a blanket as a headthrow, dons his mask, and carries a turtle rattle to impersonate Shagodyowēhgo'wa', whose heavy tread shakes the earth.

2. Common Faces of the forests are cripples. Masks of the doorkeeper type frequently appear together with the Common Faces, and since the ritual prescribes a crawling posture for Common Faces and erect stature for doorkeepers, the bearing and gestures of the actor are more important than the type of mask he wears.

1. THE BEGGARS AT THE MIDWINTER FESTIVAL AT TONAWANDA ARE A MOTLEY GROUP OF BOYS WHO SOMETIMES "TAKE SICK" AND JOIN THE SOCIETY.

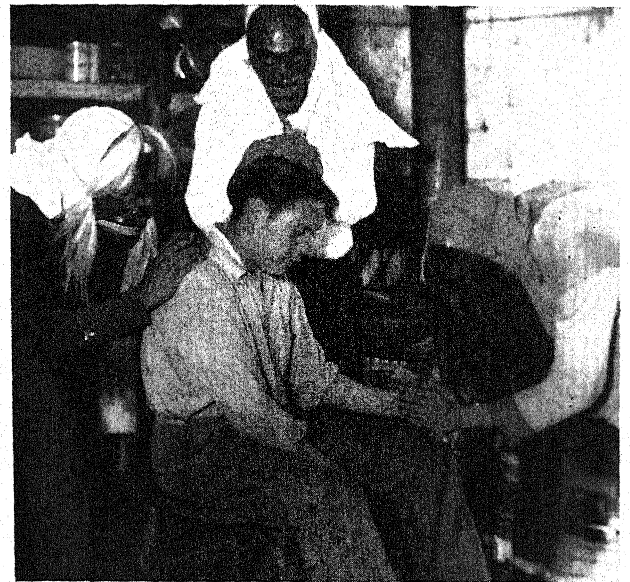


2. AT COLDSPRING AMONG THE SENECAS A BLACK MASK IS SELECTED TO DANCE IN THE SCCIETY OF MYSTIC ANIMALS (HADI·''DO·S) CEREMONY.

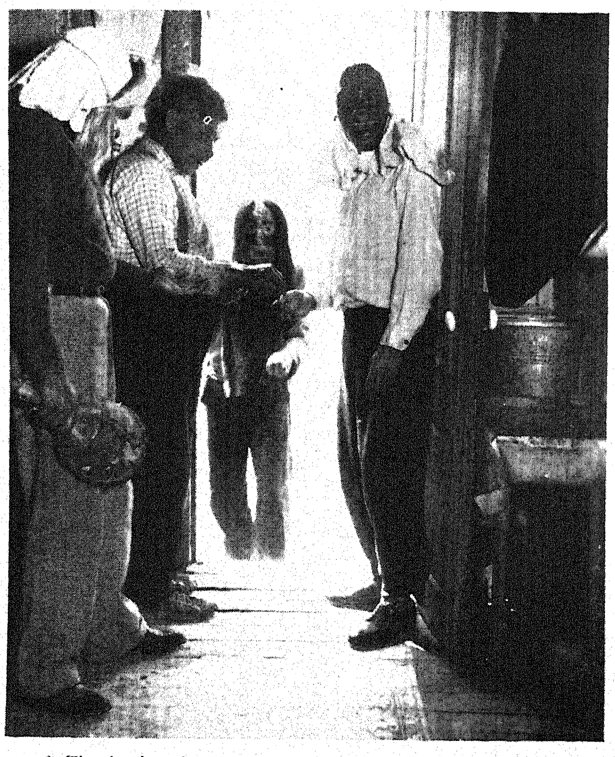
1. The Faces enter crawling.

2. Tobacco-burning invocation at the fire.

THE ORDER OF COMMON FACES WHO ENTER A HOUSE AND CURE.



1. They cure by blowing hot ashes.



2. The ritual conductor pays their leader tobacco and they depart.

THE ORDER OF COMMON FACES WHO ENTER A HOUSE AND CURE.

1. THE FACE CARVED ON THE LIVING BASSWOOD TREE.

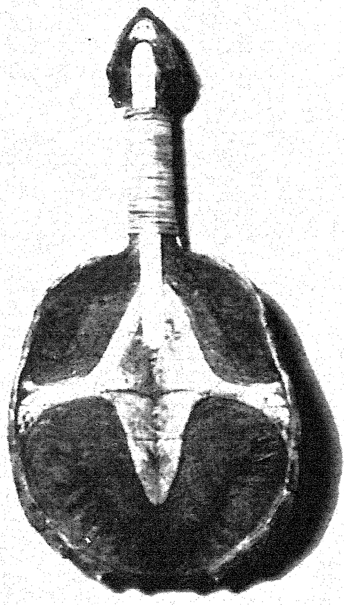
Courtesy of the Museum of the American Indian, Heye Foundation, New York.

2. THE OWNER SUPPLICATES HIS MASK WITH TOBACCO OFFERINGS WHEN IT FALLS, WHENEVER HE DREAMS OF IT, AND WHEN HE LOANS OR SELLS IT.

1. Hollowing out the inside of the mask with a bent farrier's knife.

2. Cutting the teeth and mouth detail.

CHAUNCEY JOHNNY JOHN MAKING A MASK.

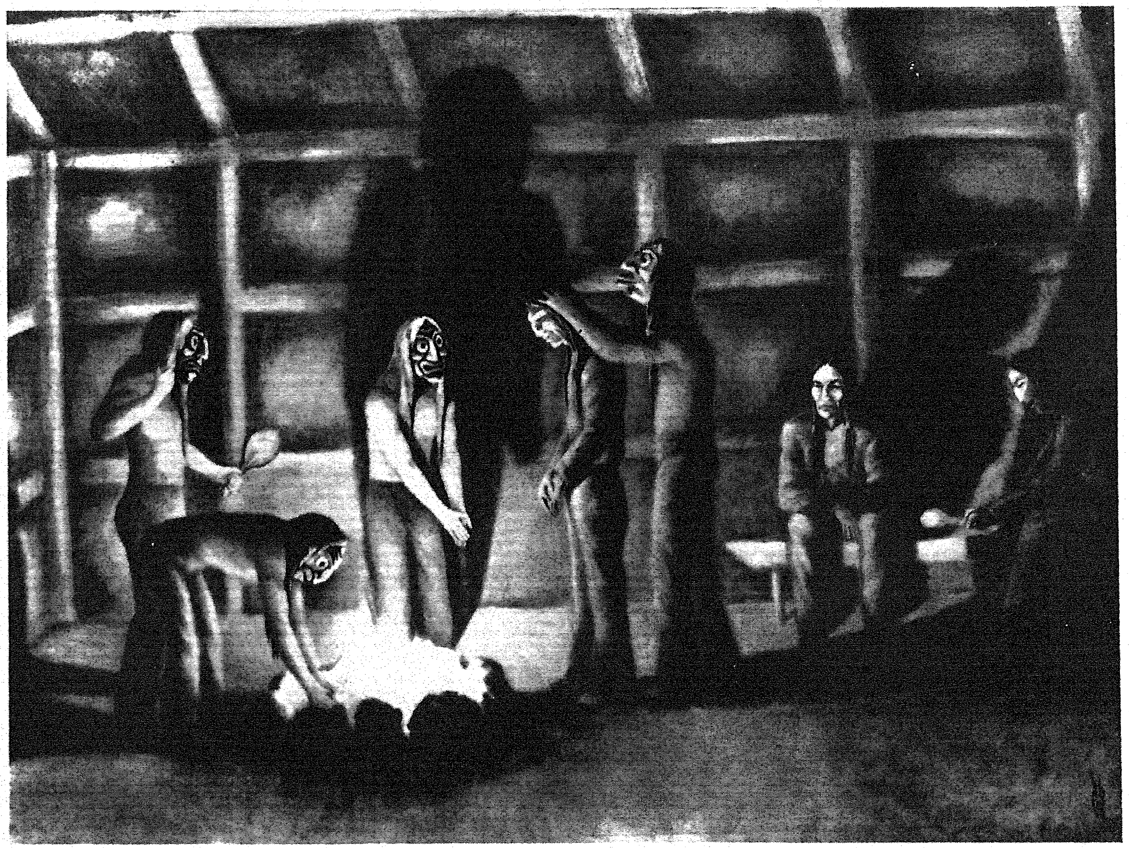


1. Snapping-Turtle Rattle. Peabody Museum, Yale University.

2. Chauncey Johnny John Making a Bark Rattle.

THE DOORKEEPER.

Shagodyowéhgo·wa· permits no one to enter or leave during his ritual. The mask, from Cattaraugus Reservation, is the property of the Rochester Museum of Arts and Sciences.



THE CURING RITE OF THE COMMON FALSE FACES.

Painting by Ernest Smith, Seneca Indian artist of the Tonawanda Reservation.

THE BEGINNINGS OF CIVILIZATION IN EASTERN ASIA[1]

By Carl Whiting Bishop
Freer Gallery of Art

[With 10 plates]

GEOGRAPHICAL POSITION OF THE FAR EAST

To understand the beginnings of civilization in the Far East, we must view them in the light of the laws that govern cultural progress everywhere. Especially must we consider the region's geographical position and relationship to other lands. As a glance at a map, or better still a terrestrial globe, will show, it occupies a marginal portion of the Eurasiatic continent taken as a whole. That this fact carries with it certain implications, the study of culture-building in general abundantly reveals.[2]

The sea routes which link eastern Asia with the rest of the world we may ignore; for their development did not occur until long after the period of beginnings had passed.[3] There were, however, two great land routes between East and West. Of these, one connected northeastern India, by way of Burma, with western China; while the other—the famous "corridor of the steppes"—extended eastward from the Carpathian Mountains and the Black Sea region right across most of Asia. These natural migration routes, traversed in geological times by numerous animal and vegetable forms, in the human period by peoples, armies, and culture traits, have always played a part of cardinal importance in the world's history.

HOMOGENEITY OF THE OLD WORLD CIVILIZATIONS[4]

Let us here call attention to another fact also in this same connection. This is the striking uniformity in space, time, and general

[1] One of four papers constituting a symposium on The Beginnings of Civilization in the Orient, given at the meeting of the American Oriental Society, Baltimore, Md., Apr. 13, 1939. Reprinted by permission from Supplement to the Journal of the American Oriental Society, No. 4, December 1939.

[2] On the effect of marginal positions on the growth of cultures, see e. g., Roland B. Dixon, The building of cultures. New York and London, 1928; reference on pp. 272 et seq. and passim.

[3] Seagoing ships with sails are not mentioned in the Chinese records until the third century A. D.

[4] The late Dr. Berthold Laufer discussed certain elements of this phenomenon in an important paper, Some fundamental ideas of Chinese culture. Journ. Race Development, vol. 5, pp. 160–174, 1914–15.

character that underlay all the great civilizations of antiquity, taken together.

In the first place, they all arose in one continuous land area—the north temperate zone of the Old World. They did so, moreover, almost simultaneously, speaking in terms of man's long total existence; though they appeared at times successively later the farther we travel, east or west, from anterior Asia. Again, they were all based on identically the same set of fundamental elements: The knowledge of

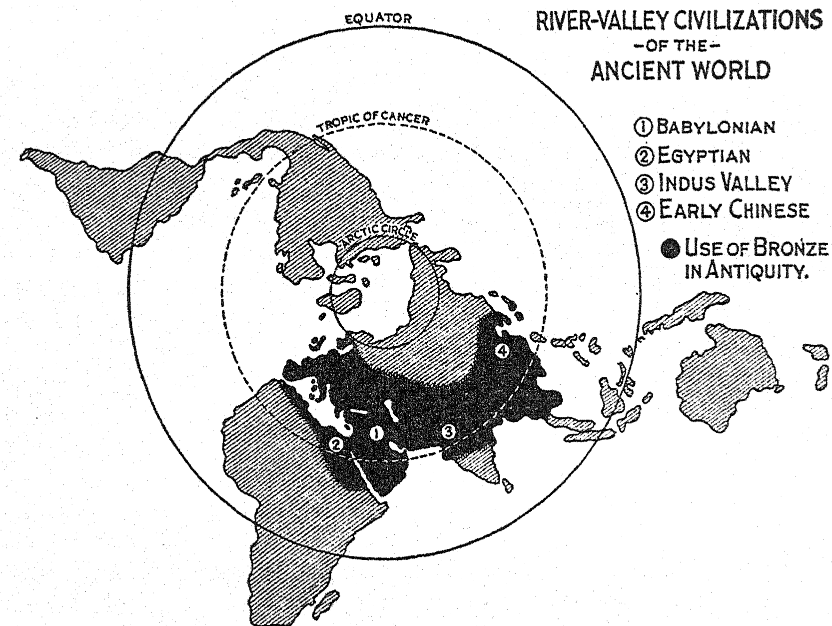


FIGURE 1.

copper or bronze, town building, the use of wheeled vehicles,[5] possession of the common domestic animals, the growing of certain cereals, especially wheat, and the idea of writing, in one form or another. Nowhere else did this group of culture traits occur in similar combination; in most parts of the world, indeed, they did not appear at all until introduced in recent historical times.

We may note that the area in question here coincided almost exactly with that portion of the earth's surface known to the ancients, either at first hand or at least by hearsay—the orbis terrarum veteribus notus of most classical atlases.

This uniformity, moreover, goes far back of recorded time. All through the north temperate zone of the Old World, but nowhere

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[5] Wheeled vehicles seem to have been developed in western Asia not later than the fourth millennium before our Era; but they took 2,000 years or more to reach Egypt—an instance of an exceedingly slow diffusion rate.

else, do we find the same general stages of culture development—first an Age of Stone, then another of Bronze, and lastly one of Iron. In most lands, man passed from the Stone Age directly into that of Iron; only in the region just named does a true Bronze Age occur.[6]

Now this homogeneity in fundamentals must signify something. How may we account for it? Not, certainly, as the result of environment alone. For three other temperate areas of continental dimensions exist—in Africa south of the Equator and in North and South America; yet none of these has ever evolved a civilization of the kind named. Nor may we lightly dismiss the problem with the facile phrase, so often heard in such connections, that "men's minds work in pretty much the same way everywhere." The reply to this assertion is, simply, that it cannot be true; for, if it were, then we ought to find similar civilizations springing up in all parts of the world, at widely separated times.

THE STONE AGE IN THE FAR EAST

On the vastly prolonged Paleolithic Period or Old Stone Age in the Far East we need not dwell here; for it has little discernible bearing on our subject.

With the succeeding Neolithic Period or New Stone Age it was otherwise. There came into being in eastern Asia several distinct cultures of this general type, some of them traceable even today.[7] The peoples possessing these were already members, in a broad sense, of those races that have occupied the region from prehistoric times down to the present.

CONTACTS WITH CIRCUMPOLAR REGIONS

The contacts of these Far Eastern Neolithic cultures seem to have been more especially with the northern portions of both the Old and the New Worlds.

A typical implement common to all parts of this vast area is, or rather was, a rectangular or semilunar stone knife, usually with one or more circular perforations. The use in winter of pit dwellings or earth lodges points the same way. Another culture trait found both in eastern Asia and in the circumpolar regions of either hemisphere was the sinew-backed or compound bow. Other instances of a similar sort might easily be adduced.

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[6] To this fact, certain indigenous civilizations of Central and South America form only apparent exceptions.

[7] As regards China especially in this respect, see Dr. Wolfram Eberhard, Early Chinese cultures and their development: A new Working-Hypothesis. Ann. Rep. Smithsonian Inst. for 1937, pp. 513–530, 1938.

PEASANT TYPES OF PREHISTORIC CULTURES

Wherever climate, soil, and freedom from forest cover allowed, the New Stone Age peoples of the Far East drew their sustenance mainly from what they could grow. Their chief source of food seems to have been millet (*Panicum miliaceum*); although rice appeared in central China before the end of the period. Neither of these plants is indigenous to eastern Asia; hence only as a result of culture diffusion, almost certainly from or through India, could they have reached China. Rice spread to that country considerably after millet,[8] and did not appear in the islands off the coast of eastern Asia until later still.

On all save the youngest Chinese Neolithic sites, the only remains of domestic animals are those of the dog and pig. On the later sites occur also bones of the sheep and ox. Those of the horse are likewise reported on some of them; but whether these belong to domestic individuals seems uncertain. A true wild horse (*Equus przvalskii*)—not merely an animal descended from escaped domestic stock—still exists in Mongolia, and may formerly have ranged over the northern Chinese plains also.

These Neolithic planting peoples of the Far East made a coarse unglazed pottery, shaped by hand (most often, perhaps, by the "coiling" process) and decorated with impressions of various kinds or with lumps and strips of clay stuck on before firing. Such ware seems, indeed, to have survived among the Chinese peasantry until far down in the historical period.[9]

Religion was pretty surely animistic in character. Among the planting peoples, at least, there seem to have been orgiastic fertility rites, perhaps accompanied by human sacrifice. In many parts of the Far East, maiden sacrifice by drowning or exposure persisted even into historical times. Today the worship of goddesses appears most commonly in areas like the eastern Asiatic coast and islands, regions marginal to the ancient Chinese civilization proper, and latest in being influenced by it. The Japanese Sun Goddess, officially claimed as ancestress of the imperial line, is probably the best known example.

Indications exist too of a former matrilineal social organization, with "priestesses" (really exorcists or medicine women) and female rulers. Society in the Far East during the New Stone Age seems indeed to have borne a decidedly feminine cast.

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[8] Numerous indications, drawn from all parts of the Eastern Hemisphere, have led me to believe millet the first cereal brought under cultivation by man.

[9] Verbal communication from T. Y. Ch'iu, of the Peking Historical Museum, confirmed by my own observations in the field.

THE CHINESE PAINTED POTTERY PHASE

On various Late Neolithic sites along or near the great transcontinental migration route already mentioned, we find pottery much finer than the coarse variety named above. This is the now famous Chinese painted ware.[10] Whether this was ever turned on some form of wheel or was entirely shaped by hand is still disputed; but it bore decoration in simple colors, chiefly red, black, and white. Designs, at first geometrical in character, later (in northwestern China at least) came to include naturalistic elements. With specimens of this latter class occur small but increasing numbers of copper or bronze trinkets,[11] perhaps introduced by trade; these yield the first faint indications that metal, already long used in the Near East, was beginning to be known in eastern Asia also.

This Chinese painted pottery seems not to have been accompanied by any distinct culture of its own. It bears rather the aspect of an individual culture trait, detached from its place of origin. Many observers believe it related genetically to similar wares found in the West, particularly in south Russia. As to its date, several independent investigators ascribe it to the closing centuries of the third millennium B. C. Others put it later; but in so doing, they hardly allow time for what we know came later.

THE CHINESE BLACK POTTERY CULTURE

In northeastern China, not long after the Painted Pottery phase of the Late Neolithic Period, we find a culture different and somewhat higher in type, though retaining many earlier elements. This culture, still quite without metal so far as we know,[12] was characterized by a smooth black earthenware of fine texture and high finish. It had domestic cattle, sheep, and perhaps horses,[13] and displayed in addition several other features long known in the Near East but new in China. Among these was the use of the potter's wheel and the building of small towns encompassed by walls of tamped earth (terre pisée). These and other traits foreshadow elements in the Chinese Bronze Age destined soon to appear.

THE CHINESE BRONZE AGE

There follows a "dark age," of unknown but certainly not long duration. Then, quite suddenly, we find ourselves confronted by a

[10] This was first made known to the world in 1922 by Dr. J. G. Andersson, then of the Geological Survey of China.

[11] The exact composition of these has, so far as I am aware, never been made public, welcome though such information would be.

[12] Metal may, however, have begun to appear in northwestern China, at the eastern end of the steppe corridor; see footnote 11.

[13] See, however, what has already been said in regard to the horse in prehistoric eastern Asia.

fairly mature civilization of Bronze Age type. How or where this came into being, we cannot yet say; but we first find it in the basin of the Yellow River during the former half of the second millennium B. C.[14]

A number of traits, all of them previously long known in the Near East, now occur for the first time in eastern Asia also. Among these was, of course, the extensive use of bronze itself for the purposes of war, ritual, and luxury (though little if at all for domestic tools and implements). Especially notable were the magnificent sacrificial vessels, used then, as long afterward, in connection with the worship of the spirits of deceased ancestors.

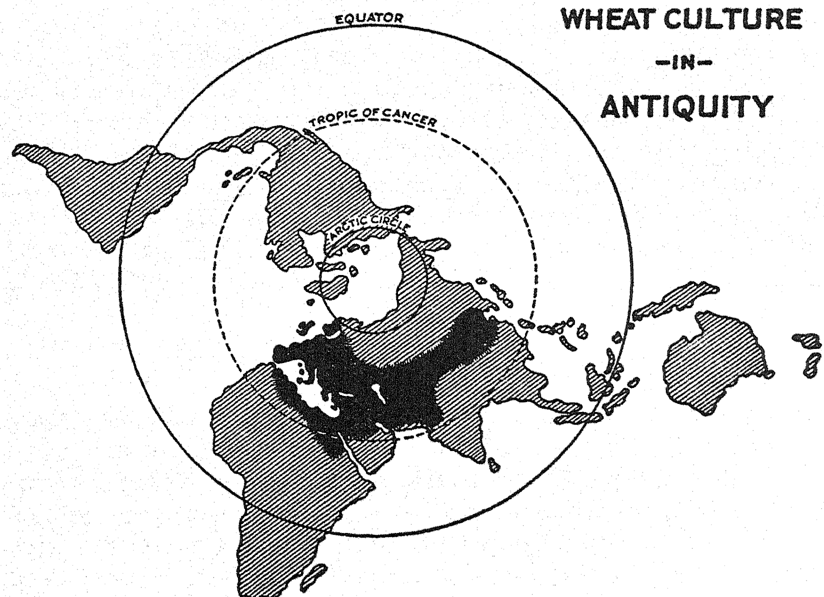

FIGURE 2.

There likewise now appears the growing of wheat, already long practiced in the Near East (where that plant is native). The area ultimately embraced by wheat culture in antiquity coincides almost exactly with that in which bronze came to be used. Further, with two exceptions (both of them Mediterranean varieties believed to have been introduced by European missionaries in the sixteenth or seventeenth century),[15] the wheats grown in China are precisely those cultivated along the steppe corridor and in the Near East.

We also now find in China the use of the chariot, drawn, just as in the Occident, by two horses yoked—not harnessed—abreast. There

[14] On this dating, now generally accepted, see my paper, The chronology of ancient China. Journ. Amer. Orient. Soc., vol. 52, pp. 232–247, 1932; ref. to p. 246.

[15] For this information I am indebted to a personal letter, of January 4, 1934, from Dr. T. H. Shen, of Nanking University.

appears, too, a new style of architecture, with colonnaded and gabled buildings, sometimes of large size; although just as later, the pillars were of wood, not stone or burnt brick. We also now encounter a system of writing, obviously with a long period of development behind it somewhere, and ancestral to the present Chinese script.

The Chinese Bronze Age was thus by no means primitive or elementary. It was nevertheless decidedly more archaic in aspect, more impoverished in content, than the corresponding civilizations of the Occident. Such a state of affairs is however quite normal to a marginal area like the Far East.

THE SHANG DYNASTY

With this somewhat belated appearance of a Bronze Age civilization in China, we reach the beginnings of that country's historical existence. The period is that of the Shang Dynasty—the first Chinese ruling house of which actual remains have been identified.[16] The line seems to have begun during the second quarter of the second millennium before our era.[17]

The Shang priest-kings, of primitive type, worshipped the spirits of their ancestors and also various divinities, of whom the chief was Shang Ti, "the Ruler Above."[18] In war, they and their followers used spears, dagger-axes,[19] and helmets of bronze, as well as compound bows and two-horsed chariots. As in the early Near East, political organization took the form of city-states, of which the one ruled by the Shangs themselves claimed allegiance and tribute from the rest. Incidentally, society was now, among the ruling class at least, organized on a rigidly patrilineal basis.

BRONZE OBJECTS OF THE SHANG PERIOD

Sites of the Shang period have yielded no bronze swords. Evidently in China as elsewhere, these weapons appeared only relatively late in the Bronze Age. We do, however, find in China at this time two types of bronze implements of no little significance. One is the socketed celt,[20] which in the Occident antedates the middle

[16] According to later Chinese legend, there was one earlier still—the Hsia Dynasty; but for the existence of the latter we have as yet no archeological evidence.

Dr. H. G. Creel has ably discussed the question of the "Hsia Dynasty" on pp. 97–131 of his Studies in early Chinese culture, Baltimore, 1937. See also my paper cited in footnote 14; ref. to p. 243. Dr. Creel's conclusions and my own, though reached quite independently, are in essential harmony.

[17] On this dating see my paper mentioned in footnote 14; ref. to p. 242.

[18] The two "Shangs" in this sentence have quite different meanings, and are written in Chinese with distinct characters.

[19] Bronze dagger-axes had been used in the Occident also before the invention of bronze swords in that quarter of the globe.

[20] On the distribution of the socketed celt, see C. G. Seligman, Bird-chariots and socketed celts in Europe and China. Journ. Roy. Anthrop. Inst., vol. 52, pp. 153–158, 1920; ref. to p. 154.

of the second millennium B. C. and has been traced there to still earlier forms. The other is the socketed spearhead, evolved in the West before the beginning of the same millennium from an earlier tanged type. Both implements, though absent from China in their more primitive stages, appear there fully developed during the Shang Dynasty.

THE WESTERN CHOU PERIOD

Not long before the close of the second millennium B. C., the Shang Dynasty fell before invading peoples from the west headed by a group called the Chous.[21] The chieftain of the latter then made himself king of northern China—roughly, the basin of the Yellow River. There he set up a feudal organization, primitive in type but forming nonetheless a decided advance over the mere tribute-collecting system of the Shangs.

The Chous, too, worshipped their ancestors, and also various divinities, of whom T'ien, "the Sky," was supreme.[22] They seem likewise to have introduced into China the 7-day week [23] and the employment of eunuchs as harem guards—both traits believed to have originated in the Near East.

At or not long after the Chou conquest (the point is still undecided) there appeared in northern China the custom of erecting grave mounds over the illustrious dead. This practice had already long prevailed in the steppe belt, from southeastern Europe far into central Asia. In that area, just as eventually in China, mounds were heaped over tomb-chambers (of wood or stone) richly furnished with grave goods; and further, in both areas the bodies thus interred were covered with red pigment, haematite or cinnabar.

SOCIAL GROUPS IN CHOU FEUDALISM

The Chinese civilization of earlier Chou times was the possession mainly of a small ruling class. The masses, on the other hand, retained much of the ancient Neolithic culture of their ancestors.[24] For this we have evidence both in ancient literary notices and in the abundance of stone implements and primitive pottery found on, or just beneath the surface of, the soil. Further, in line with what has already been indicated, while weapons of bronze are common on Chinese sites, industrial tools hardly ever occur.

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[21] On the probable date of the Chou conquest, see my paper cited in footnote 14; ref. on p. 237.

[22] T'ien and Shang Ti (the chief god, as we have seen, of the previous dynasty) were eventually equated with each other, much as Zeus and Jupiter, originally quite distinct, came to be identified.

[23] The Shangs, prior to their overthrow by the Chous, had used a "week" or day-period of 10 days.

[24] On the survival of Neolithic types of pottery among the Chinese peasantry of early historical times, cf. footnote 9.

THE EASTERN CHOU PERIOD

For some 300 years (ca. 1050–770 B. C.) the Chou capital remained in northwestern China, just at the eastern gateway of the steppe corridor. The eighth century B. C. however, brought a fresh attack from the west, by a people known as the Jungs. This forced the ruling dynasty eastward, deeper into north-central China. It thus lost its political power; but its sacerdotal character kept it in place for some 500 years longer, until the third century before our era.

In the Near East, by the end of the second millennium B. C., bronze had begun to give place to iron. In eastern Asia the Bronze Age lasted until considerably later; but it displayed from first to last a

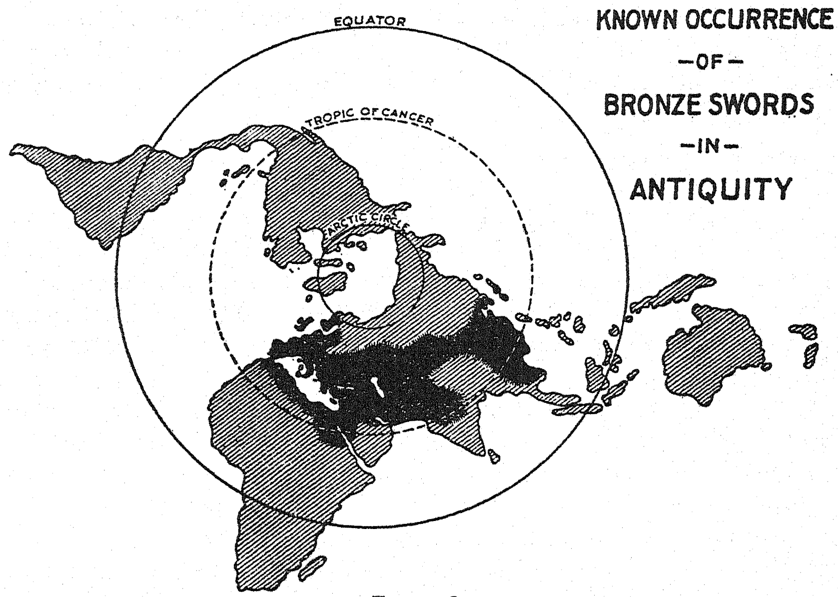

FIGURE 3.

character backward and undeveloped by comparison with those of the Occident. Whole categories of bronze objects found on western sites (particularly those of the Late Brone Age) are rare or entirely lacking in China. Among such objects are bronze pails, sickles, hoe-blades, fishhooks, razors, pins, fibulae, shields, trumpets, and many others.

Of such "culture lag," the part played in ancient China by the bronze sword provides an excellent illustration. In the Occident that weapon, after undergoing a long and complex evolution from very primitive beginnings, had reached a developed form by the second millennium B. C. In China, on the other hand, the bronze sword does not occur

at all until a thousand years later, after the Chou conquest.[25] In the Near East by that time it was already being superseded by the sword of iron.

The rather undeveloped type of bronze sword—in reality scarcely more than a dagger—found from Hungary eastward all along the steppe belt was that which eventually appeared in China. It was undoubtedly introduced into that country by the nomads—possibly the Jung people already mentioned as having attacked the Chous in the eighth century B. C. In any case, China lies almost at the eastern border of the bronze-sword area, and the variety found there underwent far less evolution than did those of the Occident.

Another example of culture diffusion is that afforded by the horse-drawn chariot. That engine of pageantry and war originated in western Asia, and spread thence both east and west over much of the north temperate zone of the Old World. It survived latest in marginal areas like China on the one hand and the British Isles on the other.

DOMESTIC ANIMALS AND CULTIVATED PLANTS IN ANCIENT CHINA

Certain species of animals and plants had slowly been brought under human control in the Near East before the fourth millennium B. C. Far later, many of the same forms appeared in China also, around the time when the Bronze Age itself began there. Whether they did so one by one, at different times, or all together, as parts of an integrated culture complex, we cannot yet say.

Be that as it may, few if any of these animals and plants were of native Chinese origin. Thus China has so far yielded no trace of a possible wild ancestor for her domestic ox. Again, the Chinese sheep appears not to be derived from the wild species which still occurs in the mountains of the northwest, but from a western wild form, the urial (*Ovis vignei*), also ancestral to certain early Occidental forms. Nor does the Chinese domestic horse seem to be descended from the Mongolian wild form; it must, on the contrary, have been introduced, already domesticated, from some western region.[26]

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[25] On this point see, e. g., Olov Janse, Notes sur quelques epées anciennes trouvées en Chine. Bull. Stockholm Mus. Far Eastern Antiquities, No. 2, pp. 67–134, 1930; ref. on p. 93.

At the time when they conquered northern China, the Chous, like the somewhat earlier Vedic Aryans when they first occupied northwestern India, seem to have had bronze daggers but not swords. In many other ways also, the cultures of the two peoples present interesting parallels.

[26] The domestication of any wild species is an exceedingly slow process, while the horse does not appear in China until rather late. Further, certain details of conformation, particularly of the skull, suggest kinship with the western domestic breeds and not with the Mongolian wild horse (*E. przvalskii*). That the latter has crossed with it to a slight extent seems certain, however.

The domestic fowl, not identified on Chinese Neolithic sites but known by Shang times, must have come from India; for its wild ancestor, the red jungle fowl (*Gallus ferrugineus s. bankiva*), occurs in that country but not in China. From India, too, seems to have come the basic stock of the domestic water buffalo.[27]

Moreover, not only did the ancient Chinese acquire most of their domestic animals as culture loans from abroad; but they failed to make as full use of them as did, for example, the ancient peoples of the Near East. Thus, though a dairy economy and the use of the ox-drawn plow had both long been known in the latter quarter, the one trait was never adopted by the Chinese, the other not until around the fourth century B. C.[28] Again, though the Chinese have had sheep

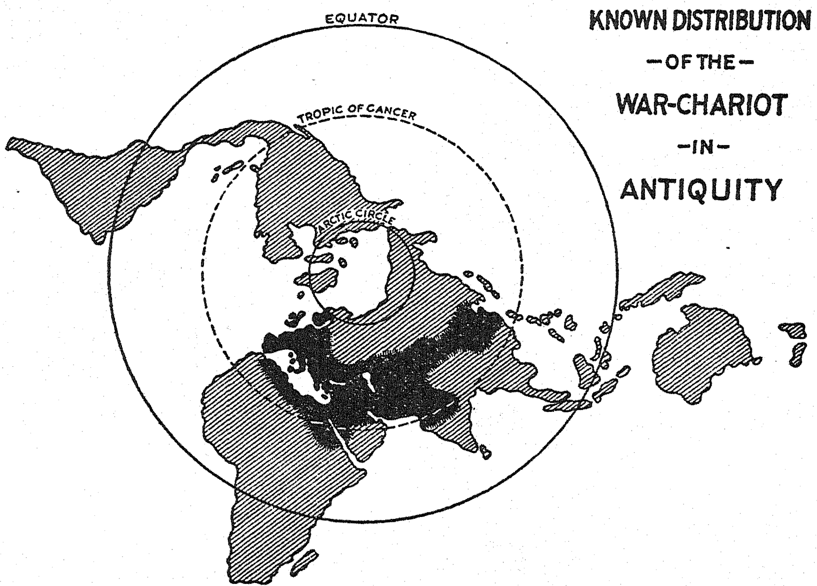

FIGURE 4.

from late prehistoric times onward, unlike the peoples of the Near East they have never made or used woolen cloth.

China's cultivated plants likewise have been derived largely from other lands. Millet, rice, and sorghum (kao-liang or "giant millet") came from India, just as did sugarcane and cotton later on. Wheat reached China about the beginning of her belated Bronze Age, from the West. Similarly (though of course not until long afterward)

[27] The Chinese water buffalo shows far less modification under domestication than do the Indian breeds. It would seem therefore to have received a large infusion of the blood of the wild form which we know once occurred in China.

[28] On the latter point, see my paper, Origin and early diffusion of the traction-plough. Antiquity, vol. 10, pp. 261–281, 1936; ref. to p. 278. The article has been reprinted in the Ann. Rep. Smithsonian Inst. for 1937, pp. 131–547, 1938; ref. on p. 545.

maize, potatoes, tobacco, and other plants were introduced from the Americas. Instances of this phenomenon, in regard both to plants and to animals, might easily be multiplied.

THE RISE OF NOMADISM

By the first half of the first millennium B. C., an important cultural development, the rise of pastoral nomadism, had begun to take form in central Asia. That region, as abundant remains show, was once occupied by a sedentary planting population similar to that of Neolithic northern China, already mentioned. Apparently about the time named, however, we find indications of a change. How far this was due to growing desiccation we do not know definitely,[29] but its form

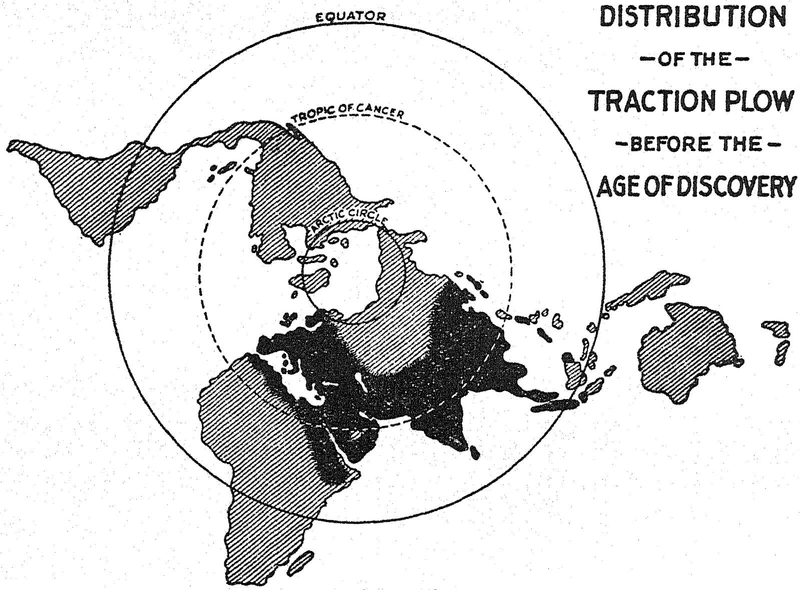

FIGURE 5.

was determined by the acquisition of domestic animals—sheep and cattle—adapted to a pastoral and nomadic manner of life.

The predecessors of the present peoples of central Asia seem to have gone about on foot.[30] They knew the horse-drawn chariots of their Chinese neighbors, but never adopted them, probably because their own cultural level was too low. During the earlier half of the first

[29] That some climatic change has occurred seems certain. On the fluctuations in level of the Caspian Sea cf. Ellsworth Huntington, The pulse of Asia, New York and Boston, 1907, passim. At the opposite end of Asia, northern Chinese Neolithic sites have yielded remains of warmth- and moisture-loving animals, notably the water deer (*Hydropotes inermis*) which could not survive there today.

[30] More than one ancient Chinese text, referring to wars with the northern barbarians even as late as the sixth century B. C., says, "They fight on foot, but we in chariots."

millennium B. C., however, first in western Asia, then a little later along the northern borders of China, we find a growing use of mounted troops. How this development took place, we cannot say; but the analogous one that occurred among the American Plains Indians when they acquired the horse from the Spaniards affords some illuminating suggestions.

BRONZE GIVES PLACE TO IRON IN THE FAR EAST

In the Occident, bronze gave place to iron far earlier than in China. In the latter country the change did not begin until about the middle of the first millennium B. C., and was not completed until shortly before the commencement of the Christian Era.

Meanwhile the older metal had diffused itself well beyond the limits of the ancient Chinese culture group proper into various marginal areas. In these the Bronze Age survived even later than in the Yellow River basin itself. Thus, in extreme southern China and the adjacent portions of Indo-China iron did not supplant bronze (under Chinese influence) until just after the beginning of our era. In Korea too we find a belated Bronze Age, introduced there from China probably during the Eastern Chou period. From the peninsula bronze soon spread to southern and western Japan; but before it had had time to reach the east and north of that country, iron overtook and supplanted it. These events marked the definitive close of the Bronze Age, and the commencement of that of Iron in the Far East.

SOCIAL AND CULTURAL DEVELOPMENTS DURING THE LATE CHOU PERIOD

During the latter part of the Chou period Chinese feudalism gradually crumbled. Among the causes were the supplanting of the old chariotry (the arm par excellence of the feudal nobles) by bodies of militarily more efficient horse-bowmen, copied, as the old Chinese records expressly state, from the northern nomads, and the rise of a money economy which slowly replaced the ownership of land and serf labor as the source of wealth and power. There emerged in place of the older political system a number of large centralized states which waged frequent war on one another and paid scant heed to the claims of their nominal suzerains, the Chou kings. In this historical process the compelling need for the consolidation of authority over systems of hydraulic engineering—of flood control and irrigation—played an important part. But the period, though thus politically unstable, was a most fruitful one in the development of Chinese civilization, particularly in the realm of thought.

FOUNDING OF THE CHINESE EMPIRE

During the third century B. C. there arose in northwestern China a great conqueror and organizer, Shih Huang Ti (to give him his later appellation), king of the aggressive state of Ch'in.[31] This man of genius subdued the other Chinese states and united them into a single centralized and bureaucratic empire, with himself as its absolute ruler—the most enduring political achievement ever wrought by man.[32]

Systems of government closely similar, even in their details, had arisen not long before in lands farther to the west—in Persia under Darius the Great, in India under Chandragupta Maurya. This new principle in state building appeared in all three countries within a period of about 3 centuries, roughly 500–200 B. C. It did so, moreover, at successively later dates as we pass from the Near to the Far East.

With this founding of a centralized empire, the civilization of China, which became in time, incidentally, that of all eastern Asia, was fairly launched on its great historical career.

SUMMARY

In the foregoing paper we have purposely avoided attempts at interpretation, necessarily more or less subjective as these are. We have, on the contrary, simply stated ascertained facts, and allowed these to speak for themselves.

As we have seen, civilization appeared earliest in the Near East. There, certain animals were domesticated, certain plants brought under cultivation; there, too, various basic inventions were made and city life first arose. To accomplish all this required a long period, probably of several thousand years.

In eastern Asia we found things quite otherwise. Many of the above culture traits appeared there too; but they invariably did so far later, and, relatively speaking, at an already fairly advanced stage of evolution. Nothing has been found to suggest their independent origin there, while in certain instances we found definite evidence of their ultimate derivation from the West. These traits displayed in the Far East, moreover, just that archaic and fragmentary nature characteristic of marginal areas everywhere.

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[31] From the name of this state almost certainly came our own for the whole of China. Those who dispute this, usually on the ground that the latter name occurs (in India) earlier than the founding of the Ch'in empire, forget that the state of Ch'in had already annexed the eastern ends of both the overland routes which link China with the West.

[32] The Chinese Empire lasted, in substantially the form devised for it by its creator, for over 2,000 years—221 B. C.–A. D. 1911.

Mainly, therefore, it would appear, to the stimulus imparted by cultural diffusions from the ancient Near East must have been due the origin and fundamental type of that civilization which eventually took form in eastern Asia. The case seems, in short, not to have been one of separate local invention, but of perfectly normal culture drift, acting steadily, though most often imperceptibly, during hundreds, in some cases, even thousands, of years.

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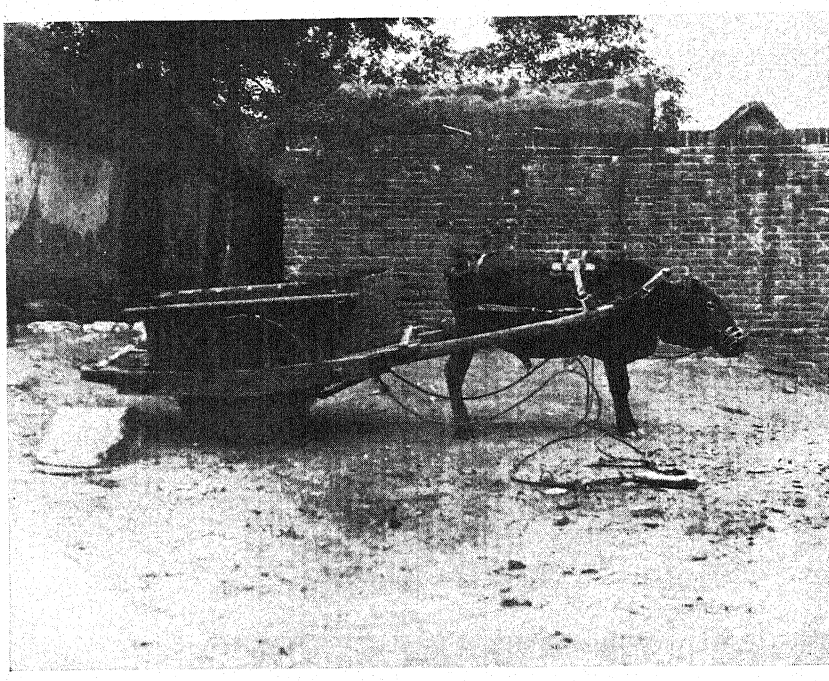
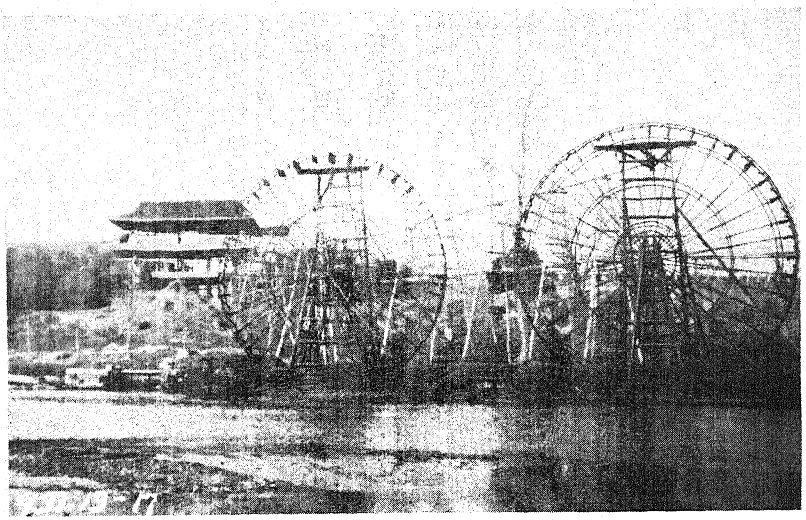


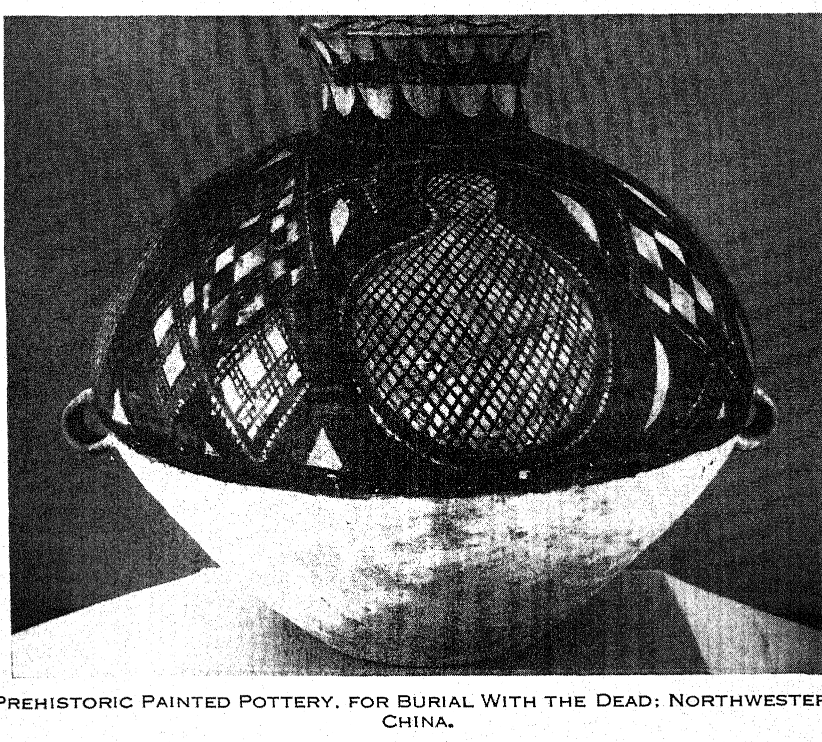
1. PRIMITIVE TYPE OF CART, WITH MERELY A PAIR OF SOLID WOODEN DISKS FOR WHEELS; STILL SURVIVING IN CHINA DOWN TO THE PRESENT DAY.

2. EARLY TYPE OF WHEEL, ANTEDATING THE USE OF RADIAL SPOKES; COMMONLY SEEN IN NORTHERN CHINA.

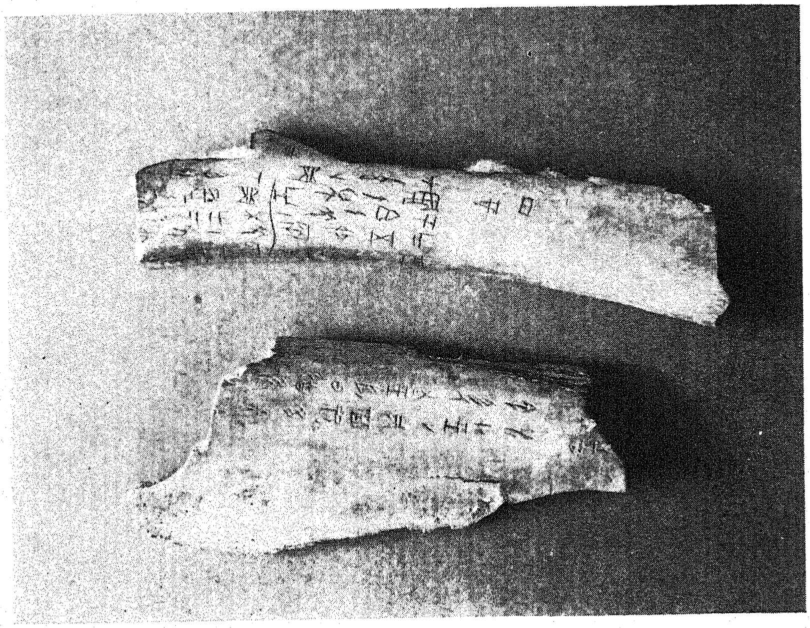


1. CHINESE WATER WHEELS, NORTHWESTERN CHINA.
Similar ones occur right across Asia as far as Persia at least.

2. CHINESE GRINDSTONE, OF A FORM FOUND AS FAR TO THE WEST AS THE MEDITERRANEAN REGION.

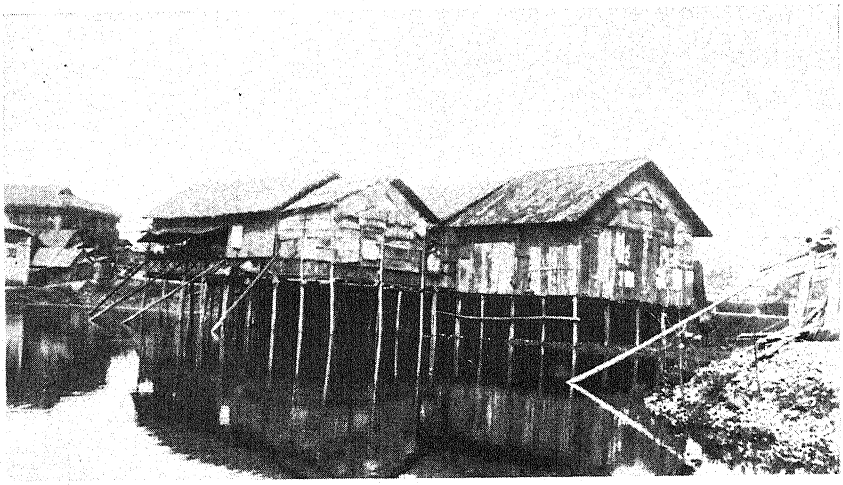


PREHISTORIC PAINTED POTTERY, FOR BURIAL WITH THE DEAD; NORTHWESTERN CHINA.

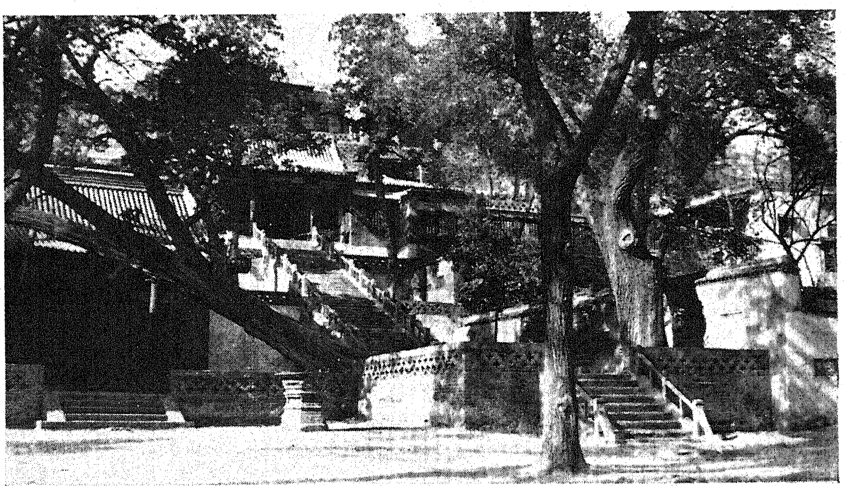


1. EARLIEST KNOWN FORM OF CHINESE WRITING (2D MILLENNIUM B. C.), INCISED ON BONE AND TORTOISE SHELL AND PROBABLY ON WOOD AND BAMBOO ALSO.

2. ANCIENT CHINESE RITUAL BRONZE VESSELS; ABOUT MIDDLE OF 1ST MILLENNIUM B. C.



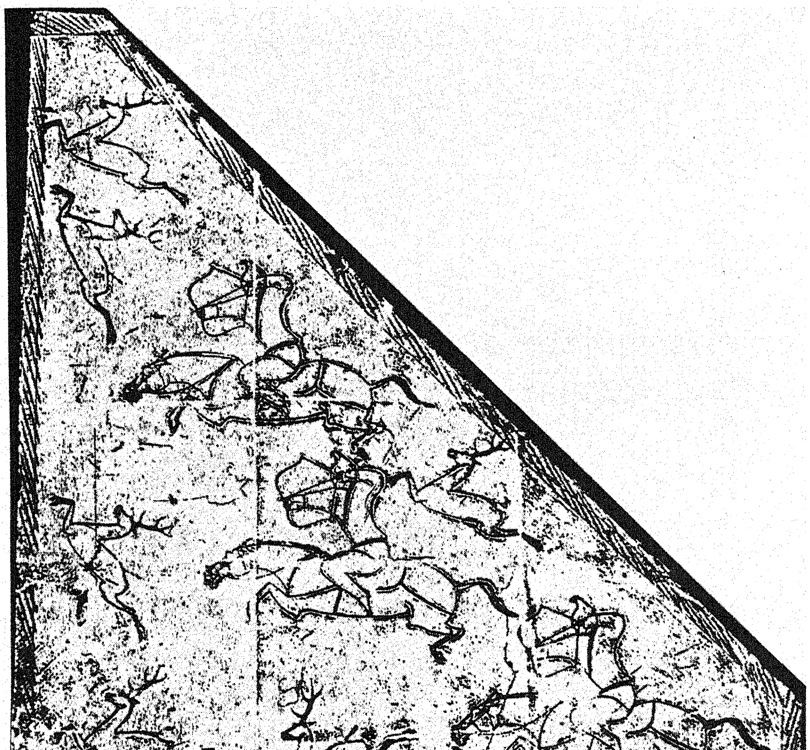
1. SURVIVAL OF USE OF PILE DWELLINGS; SOUTH-CENTRAL CHINA.



2. TEMPLE AND GROUNDS IN NORTHWEST CHINA, BUILT AT A SACRED SPRING.

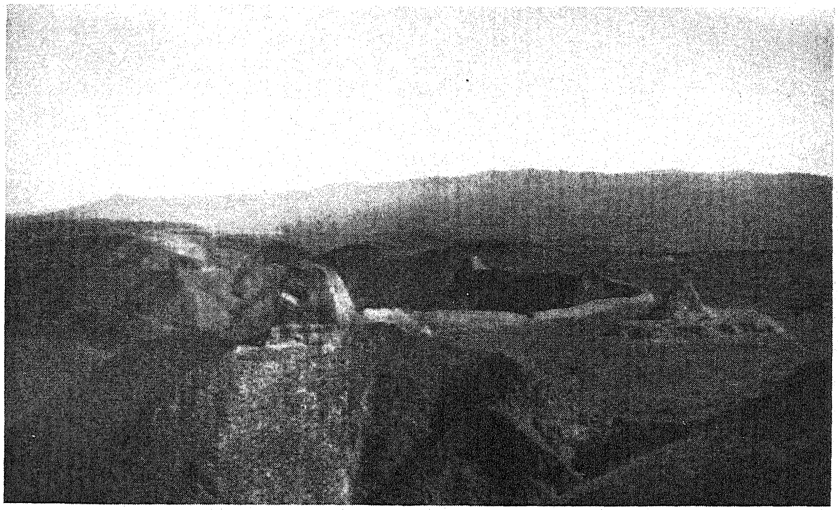
1. ANCIENT CHINESE CHARIOT OF AROUND 2,000 YEARS AGO; FROM A RELIEF OF THAT TIME.

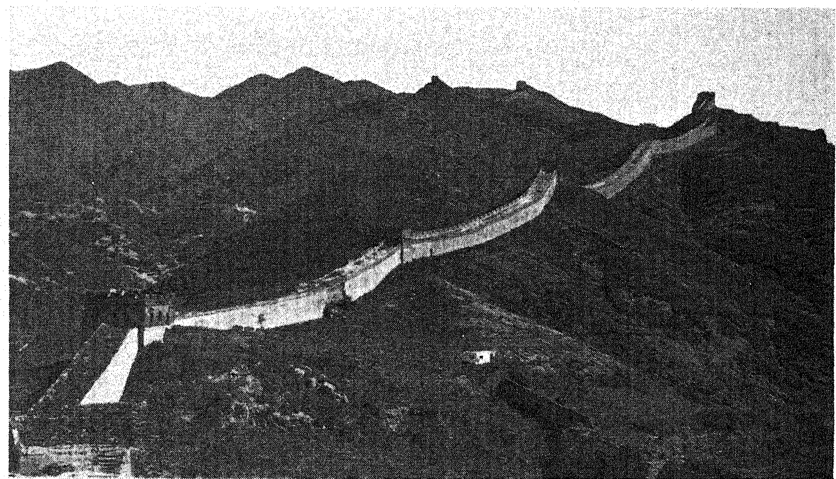
As in the Near East and in Europe, so too in China, chariots came into use much earlier than riding on horseback.



2. CHINESE MOUNTED HUNTSMEN OF THE LATE 1ST MILLENNIUM B. C., FROM A DECORATED TILE OF THAT PERIOD.

Note absence of stirrups and of true saddles, not known until later.

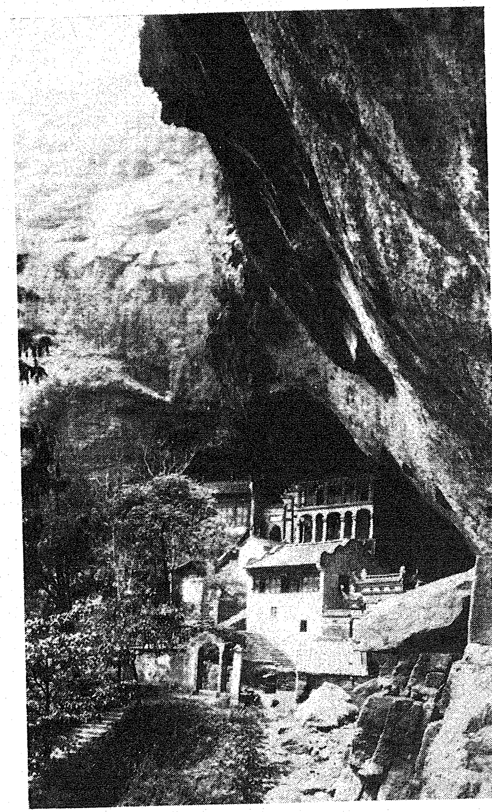




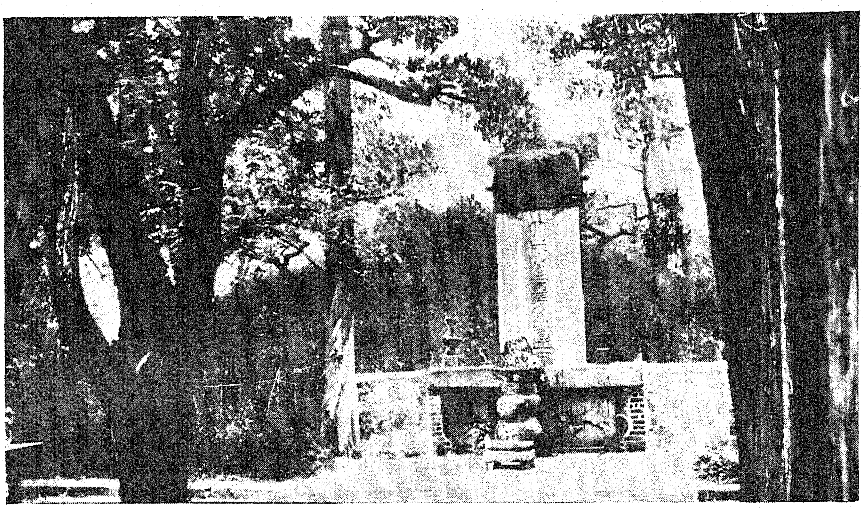
VIEWS OF THE GREAT WALL OF CHINA.

The original rampart, now almost effaced, was merely one of earth, as here shown; but in recent centuries the structure was faced with brickwork at strategic points.

1. TREE WORSHIP IN NORTHERN CHINA; NOW DISCOURAGED BY THE AUTHORITIES AS A RELIC FROM PRIMITIVE TIMES.

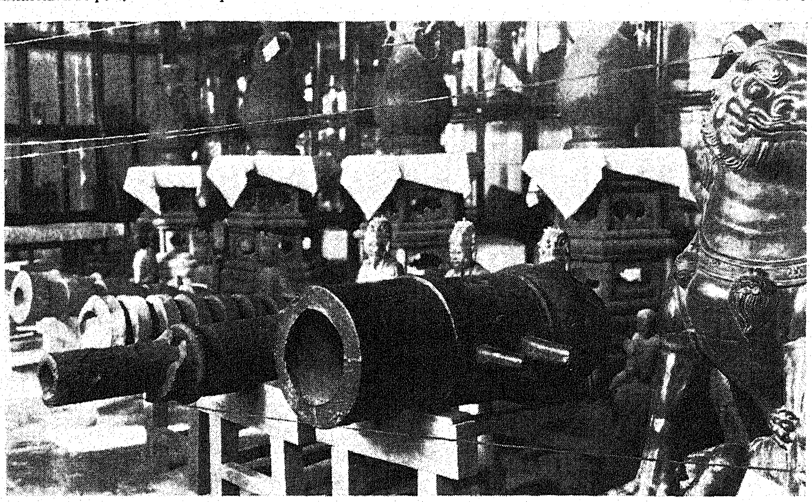


2. SACRED CAVE, WITH TEMPLE TO THE T'IEN LUNG WANG ("HEAVENLY DRAGON KING"); SOUTH-CENTRAL CHINA.



1. REPUTED GRAVE MOUND OF CONFUCIUS (D. 479 B. C.).
The stone tablet is comparatively recent.

2. GRAVE MOUND OF CH'IN SHIH HUANG TI (D. 210 B. C.), FOUNDER OF THE CHINESE EMPIRE AS WE KNOW IT, AND BUILDER OF THE GREAT WALL OF CHINA.



1. OLD CHINESE CANNON (THE LARGE "BOMBARD" IN FOREGROUND), BEARING A DATE (IN CHINESE) CORRESPONDING TO A. D. 1378.

2. STREET SCENE IN T'UNG KUAN, THE CHINESE GIBRALTAR; THE HILL IN THE BACKGROUND HAS BEEN ALMOST IMPREGNABLE TO ASSAULT.

STONEHENGE: TODAY AND YESTERDAY [1]

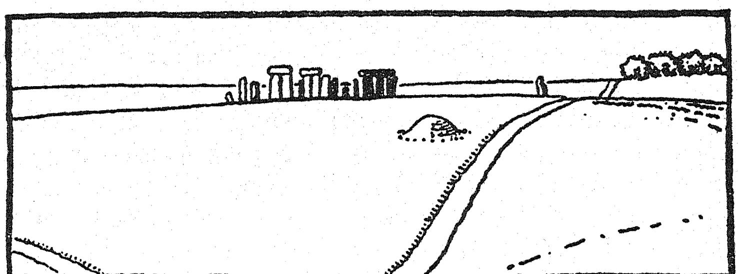
By Frank Stevens, O. B. E., F. S. A.
Director of the Salisbury Museum

(With plans and illustrations by Heywood Sumner, F. S. A.)

[With 1 plate]

INTRODUCTION

Stonehenge (in the county of Wiltshire, England) is a monument with a reputation which has attracted visitors of all nations and of every class for very many years. No prehistoric monument can boast such a bulky bibliography, which runs into thousands of books, pamphlets, and newspaper notices.



Stonehenge, Today – Looking West.

Figure 1.

There would seem to be a fascination about the stones which attracts the writer and invites him to set down his views and conclusions on the subject of this famous circle. And this is not hard to explain. It is due to the atmosphere of mystery in which Stonehenge was formerly enveloped which led past generations to indulge in random speculations as to its origin and use. The quality of these speculations varied. Some were frankly wild guesses; others were of a quasi-scientific nature, set out in solemn print with all the impressiveness of a scientific achievement.

[1] Published by His Majesty's Stationery Office, London, 1938. Reprinted by permission of that office.

At different times the Phoenicians, the Druids, the Romans, and even the Sumerians have been hailed as builders of Stonehenge. It has been the background of lurid descriptions of human sacrifice, with blazing wicker figures filled with writhing victims. It has been described as a calendar, a great tribal meeting place, and the ceremonial center of a vast necropolis.

But most of this speculation lacks confirmation. Much is based on analogy and upon similarity to other stones in other parts of the world. Analogy is not always a sure guide, and certainly similarity is not always identity. Because the Japanese or Polynesian may erect a "Trilithon"[2] for their religious rites and ceremonies, it does not follow that Stonehenge was erected for a like purpose.

So much of this speculation has been printed and circulated, copied and recopied by guidebooks, that it is very difficult for the present-day visitor to disentangle truth from picturesque fiction or guesswork. In addition, it is only recently that archeology has come to be reckoned as a definite science and not the spare-time amusement of the squire with a taste for investigating burial mounds to see what was inside them.

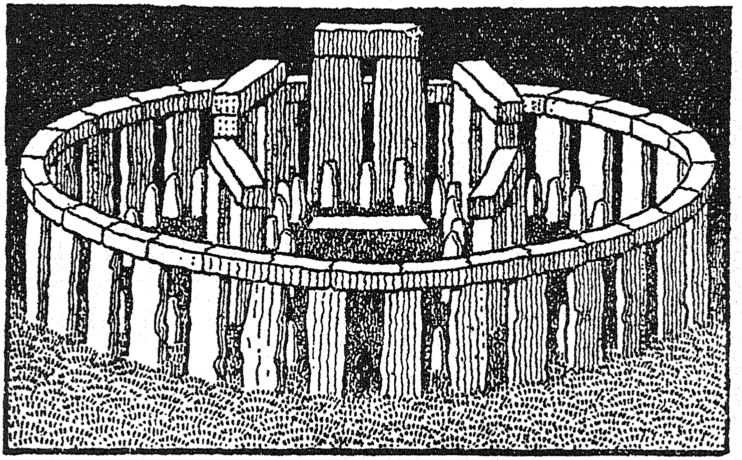
To see Stonehenge intelligently, therefore, the visitor should disabuse his mind of all theories and preconceptions, and concentrate on the definite evidence which scientific exploration can lay before him today. The aerial photograph will reveal a vanished trackway. The careful excavations of Professor Gowland, Colonel Hawley, and R. S. Newall will present an array of objects which can afford a definite conception as to the date of building. The petrologist will decide the origin of the rocks used in construction, and finally the archeologists will produce their contribution, showing the migration of tribes from the Continent of Europe to the British Isles, bringing with them their own peculiar customs of burial and religion.

In this sense, then, Stonehenge may come to be regarded not as an isolated monument but rather as the climax of a long chain of stone circles introduced into this country by a civilization which came certainly from the west of Europe, if not from some even more remote source.

Today it is impossible, even after years of patient investigation, to find an answer to every problem which the circle propounds, for the very good reason that the science of practical archeology, as yet, is only in its infancy. But the conclusions which have been arrived at during the past three decades have more than a degree of certainty about them which the earlier work of a past generation lacked. Let us cling, therefore, to things capable of proof and supported by

[2] Trilithon, a structure of three stones, two upright, with the third forming an impost or lintel.

unshakeable evidence, and if that is done, it will be found that Stonehenge will prove even more wonderful than the most speculative of past writers would have us believe.



Stonehenge
as it probably was. Plan & Bird'seye View.

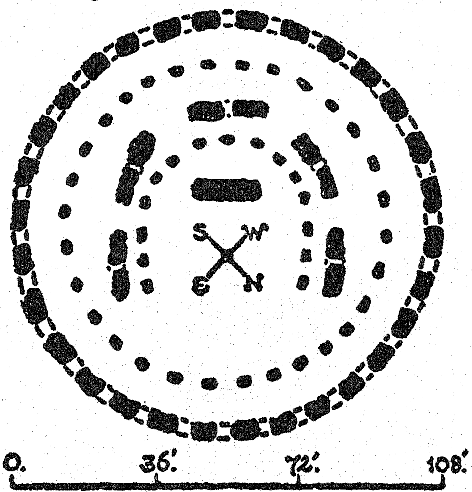


FIGURE 2.

DESCRIPTION OF STONEHENGE

The following are the chief features of Stonehenge:

(*a*) A circular earthwork 300 feet in diameter, inside which are 56 holes known as the "Aubrey Holes," 32 of which (marked by white patches of chalk) have been excavated and examined.

(*b*) An "Avenue" bounded by earthen banks approaching the circular earthwork on the northeast.

(*c*) Within the Avenue, but outside the Circle, a large unworked upright Sarsen stone, called the "Hele Stone" or "Friar's Heel."

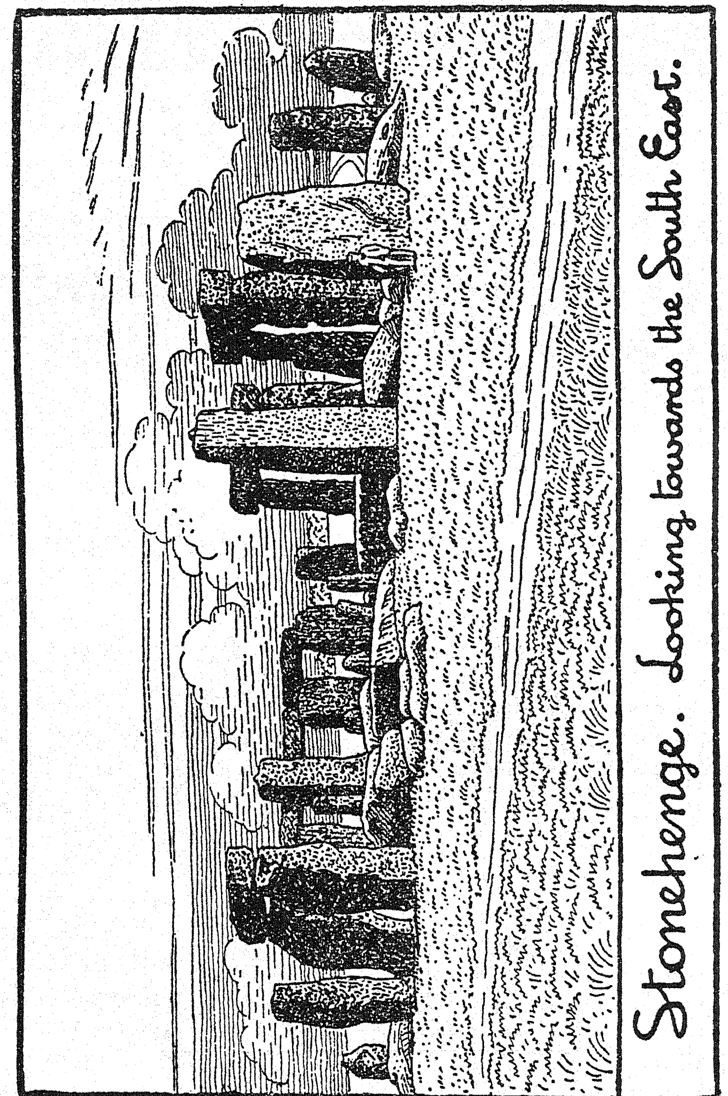


FIGURE 3.

(*d*) A recumbent slab of Sarsen within the earthwork.

(*e*) Two small unhewn Sarsens lying northwest and southeast of the Circle.

(*f*) A circle of hewn Sarsen stones, with lintels mortised to them. These lintels are fitted together with toggle joints, and the inner face

of them has been dressed, to form a circle of 98 feet diameter. Sixteen out of the original thirty uprights of these Trilithons are now standing.

(*g*) Within the circle of Sarsen Trilithons is another circle of hewn stones. These stones have been conveyed to the spot from Prescelly in Pembrokeshire. They numbered once between 40 and 50, but only 21 exist today.

(*h*) Five great detached Trilithons, arranged in a horseshoe, with the opening to the northeast. These Trilithons are graduated in height, that in the center standing 22 feet above the ground.

(*i*) An inner horseshoe of stones from Prescelly, standing from 6 to 8 feet in height. Including the stumps left in the ground, there are 12 of these stones.

(*j*) A recumbent slab of micaceous sandstone, lying under the debris of the fallen Trilithon, which most probably came from Milford Haven. This was first called the "Altar Stone" by Inigo Jones in the seventeenth century. It is 16 feet long and weighs 7 tons.

The question which is bound to arise is, How was the circle erected? Here again the process of building may be summarized briefly before entering upon more detailed explanations. The large blocks of Sarsen stone were roughly shaped in situ on the Plain before being transported to the site where the work was finished. The Prescelly stones were dressed on the spot before erection. The entire work was performed with stone tools of the roughest description, weighing from half a pound to over 60 pounds.

The large Trilithons were erected first and the Pembrokeshire stones placed in position afterwards.

STONEHENGE AND OTHER STONE CIRCLES

1. Stonehenge is probably the latest and is certainly the most elaborate stone circle in England.

2. It is the only circle in the country which contains stones which have been brought at least 180 miles.

3. The stones have been squared, dressed, and provided with lintels, with mortises, tenons, and toggle joints.

4. The horseshoe arrangement of the stones is most uncommon.

5. Most of the stone circles in the South of England face the northeast. Stonehenge is one of these.

6. Stone circles are to be found in South Britain, in Cornwall, Devonshire, Dorset, Somerset, and Wiltshire. They are also found in the Prescelly district in Wales.

7. Though not rich in circles, Wiltshire contains two of the most remarkable in the Kingdom—Avebury and Stonehenge.

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Avebury, the older of the two, has been partly destroyed, but when perfect was one of the largest.

Stonehenge is the most finished example of a megalithic circle in England.

THE LITHOLOGY OF STONEHENGE

Weatherworn and overgrown by lichen, it is not possible at the present day to see clearly the nature of the stones which go to make up Stonehenge. Investigation reveals the fact that the stones vary very much in material, and that, further, just as the stones are placed in systematic order, so too has the same care been exercised in the selection of the material from which each circle or horseshoe has been built.

Moreover, just as the stones can be divided into groups of uprights with lintels, or "Trilithons" and "simple uprights," so too has it been found that while all the Trilithons are composed of "local" stone known generally as "Sarsen," all the simple uprights are of Prescelly stone, or "bluestone," as it is generally called. This term must be understood in a very comprehensive sense, since the simple uprights show considerable variation in structure, but one and all are foreign to the County of Wiltshire, whereas the larger Sarsen blocks, which were formerly scattered all over the Wiltshire Downs, still exist in some parts in considerable numbers.

THE SARSEN STONES

All the large stones comprising the Trilithons are "Sarsens" which have come from Wiltshire. They are found in the form of boulders, and are picturesquely called "grey wethers." The name is an apt one, since in North Wiltshire, where they are more plentiful, they certainly suggest a flock of titanic sheep reclining at ease on the pasturage of the Downs. The hand of man has been heavy upon the Sarsens, in a country which has little stone and that only in the form of flint. Sarsens have been even quite recently used for paving stones and kerbs in Wiltshire towns. They are also to be found in the walls of churches, while the village of Avebury itself affords an example of how the Great Circle there has been depleted for building purposes. No doubt the stones were far more plentiful in prehistoric times, but even admitting this, it seems hardly likely that the large tabular blocks used at Stonehenge could have been found in the immediate neighborhood. On closer examination the "Sarsen" shows itself to be a sandstone, formed by the natural cementing together of the sand and gravel which overlay the chalk in Tertiary times. The stone is of very uneven texture, some specimens being very compact and hard, while others are friable and easily disintegrated. One thing is very certain, however; the building of both

Avebury and Stonehenge called for exceptionally large stones of a special shape, which would mean that they had to be sought out and selected over a fairly wide area, and this applies particularly to the "tabular" Sarsens, which most readily lent themselves to the purpose of the Trilithons at Stonehenge.

With the exception of the "Friar's Heel," all the Sarsens at Stonehenge are tabular blocks.

THE PRESCELLY STONES

The Sarsens usually awake the greatest interest by reason of their size and the difficulties presented by their erection to a primitive race.

But a far greater problem is presented by the Prescelly stones, which, though smaller in size, have traveled to Wiltshire from Pembrokeshire, a distance of 180 miles as the crow flies.

For many years the place of origin of these stones was a matter of controversy. One theory advanced was that they had been brought to Salisbury Plain as boulders of "glacial drift." This has been heavily discounted by the fact that no pebbles of that particular stone appear in the local gravels. Others have sought their home in Cumberland, Devonshire, and Cornwall. Finally, the late Dr. Thomas proved beyond all question that their origin was in the hills at Prescelly.

Today 34 of these stones remain to us, and have been grouped as follows:

Dolerites	29	
Rhyolites	4	
Micaceous sandstone	1	("Altar Stone")

The dolerites are crystalline igneous rocks, of a blue-green to greenish-gray color, with white spots varying in size from that of a pea to a walnut. This is a special characteristic of the Stonehenge dolorites.

The rhyolites are masses of volcanic rock (lava).

The micaceous sandstone (Altar Stone) differs from the two abovenamed rocks and should be regarded as apart from them. Three localities have been suggested, the Mendips, Glamorganshire, and Pembrokeshire. The Altar Stone has special affinity to the last two localities, which are more or less identical in structure, and it is almost certain that South Wales is the locality from which this stone was brought. If this is so it seems more probable that the stone came from Milford Haven than from Glamorganshire. Both dolerites and rhyolites are to be found in the Prescelly district and at no great distance from Milford Haven. The spotted dolerite of Prescelly has all

the character of the Stonehenge fragments. The same may be said of the rhyolite.

Finally, when sections of the rocks are examined under the microscope, the similarity becomes identity. Photographs of these sections are on view at the Salisbury Museum, together with a full series of

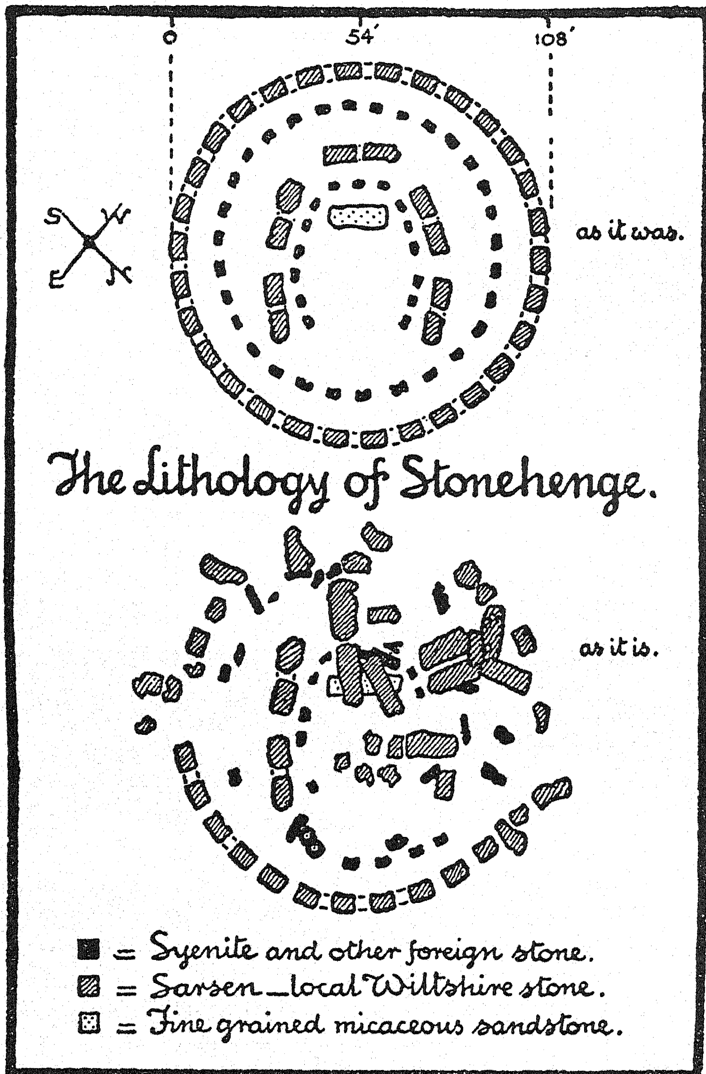


FIGURE 4.

specimens illustrating the lithology of Stonehenge. Dr. Thomas in his report adds that "the assemblage of Stonehenge foreign stones presents the significant feature of derivation from a comparatively small area where all the rock types occur together."

But there is yet another point which calls for consideration: the eastern portion of the Prescelly Mountains is extremely rich in Megalithic remains. Dolmens and the remains of stone circles are numerous; at least eight circles have been identified in the limited area from which the stones have come.

THE AVENCE, DITCH, AND AUBREY HOLES

It is extremely easy for a visitor to Stonehenge to overlook the Avenue which approaches the circle from the northeast.

This earthwork cannot be traced very readily at the present day; but in the days when Stonehenge was perfect and formed part of the life of the inhabitants of the Plain, it must have been a very marked and imposing feature of the monument. It is quite possible that there might have been an avenue of standing stones upon its banks. This is one of the points which still await future investigation. The Avenue extends from Stonehenge in a northeasterly direction for over 500 yards, and then divides into two branches, one turning to the left and proceeding in the direction of the Cursus about half a mile distant. The task of investigating this branch has not been completely undertaken. The branch which turns to the right has been traced by one of the most interesting aids to modern archeology—photography from the air.

O. G. S. Crawford, of H. M. Ordnance Survey, detected on air photographs of the Stonehenge district certain lines which indicated what he believed to be the original trackway leading from Stonehenge to the River Avon at West Amesbury. Examination and excavation revealed the accuracy of Mr. Crawford's surmise. The track, which diverges from the Avenue, does not go straight to the river, but makes a sweep round the back of Fargo Wood, over Seven Barrow Down, and so to the river somewhere near West Amesbury House. There seems to have been some purpose in this deviation, for it follows more or less the contour of the map, and avoids the steep dip in the Plain just before Stonehenge is reached by the road from Amesbury. It is even more than possible that this particular depression was, at the time Stonehenge was being built, a quagmire, and that the trackway purposely skirted the tail of it.

The straight Avenue leading to Stonehenge is quite different from the two trackways already described. It lies between ditches 71 feet apart, with 47 feet between the banks. This fine layout at once suggests a ceremonial use for the Avenue.

The Ditch and Bank which surround Stonehenge have been briefly mentioned already. They are an earthwork of a class quite unlike cattle enclosures and defensive works, and exhibit a precision in setting out which is only associated with the sepulchral and religious

earthworks of prehistoric times in this country. The custom of digging a circular ditch round a barrow or stone circle was not unusual, and it has been suggested that the Ditch and Bank were symbolical of a barrier beyond which it was tabu to pass. One peculiarity in the case of Stonehenge is that the Bank is on the inside, and not outside the Ditch.

The Ditch has suffered very greatly in the flux of time from the natural falling in of the sides, known as silting. When freshly dug it would have been 6 or 7 feet wide at the bottom and between 4 and 5 feet deep. Its dimensions vary between the above limits, and it would appear from this that it was the Bank rather than the Ditch which was the main object of the builders. It was in fact to gain material for the Bank that the Ditch was dug. A glance at the plan (omitted from this reprint) will also reveal two causeways where the Ditch ceases, one on the northeast and the other on the south. It will also be noticed that the Northeast Causeway does not lie in the center of the line of the Avenue.

Inside the circumference of the Ditch and Bank will be found a series of roughly circular patches of white chalk, marking the positions of the Aubrey Holes, which were first scientifically recorded in 1920. The discovery was not absolutely a new one, for when Aubrey, the antiquary, made his plan of Stonehenge in 1666, now preserved in the Bodleian Library at Oxford, he indicated upon it certain depressions at regular intervals inside the earthwork. Time had obliterated these depressions when Colonel Hawley and R. S. Newall began to investigate after consulting Aubrey's map at Oxford. In all, 56 holes were located in the complete circle, and 32 of these were excavated. They occur roughly at intervals of 16 feet and vary little either in size or shape, being rather over 3 feet deep and 5 feet in diameter, all more or less circular. The solid chalk which lies very close to the surface at Stonehenge, has in many cases been crushed on the lip of these holes, which suggests that the uprights which may formerly have stood in them have been pulled down. Whether these uprights were of wood or stone is still a matter of debate. That the holes contained uprights is beyond question.

Nearly every one of the 32 holes examined contained cremated human remains, and in three cases the cremation had taken place in situ. It does not follow, however, that the cremations are of the same period as the erection of the uprights; there is, indeed, evidence in one case that the remains were deposited after the removal of the upright from its chalk socket.

A very interesting suggestion has been made that the Prescelly stones originally formed this simple circle of unwrought stones, which later on were removed and dressed, to be erected in their present position within the circle and horseshoe of Sarsen Trilithons.

The diameter of the circle of Aubrey Holes is 288 feet, and the center from which this circle was struck is not that of the existing Stonehenge, but lies about 2 feet 6 inches to the south of it. The fact that Stonehenge has two distinct centers, one for the Aubrey Holes and one for the circle of Trilithons, may very well suggest that the Aubrey Holes and the existing circle at Stonehenge do not belong to the same date, and that there were two distinct periods of building at Stonehenge.

THE STONES OUTSIDE THE CIRCLE

Outside the circle of Trilithons stand four stones. One, the "Friar's Heel," stands on the northeast, inside the Avenue. The second, also on the northeast and just within the Ditch, has been named the "Slaughter Stone." The remaining two stones are on the line of the Aubrey Holes at the southeast and northwest respectively. The "Friar's Heel" and the two stones at the southeast and northwest are unworked, but the Slaughter Stone was worked. All signs of working on its exposed surface have been obliterated by time, but when it was uncovered during excavation, the tool marks on its sides were very plainly visible.

THE "FRIAR'S HEEL"

This stone is the largest of the outlying stones of the circle. It is 16 feet high and leans inward. The name is a remarkable one and is derived from a legend, whose origin is unknown, which links the stone with the Devil.

In early times the worship of stones was very common, and even the Jews were not untainted by it, and such rites were sternly reproved by Isaiah and other prophets. Later on, in Christian times, the custom continued and was forbidden by the Council of Tours and later on by Cnut. They belonged to the bad old days of paganism and were, therefore, of the Devil, and hence the "devil-legend."

Much has been written about the rising of the sun over this stone on Midsummer Day. Many people have seen it, and there are plenty of photographs showing the disk of the sun just over the peak of the stone. It should not be forgotten that the stone lies within the Avenue and is very roughly on the axis of the circle facing the so-called Altar Stone. These facts should indicate the possibility of a connection between Stonehenge and the sun. Further indication of the importance of this stone, to the builders, was forthcoming when excavation on the western side revealed a circular trench about 30 feet in diameter surrounding it. The eastern portion of this had been destroyed by the present-day roadway.

THE STONES AT THE SOUTHEAST AND NORTHEAST OF THE CIRCLE

These two unwrought stones stand just inside the Ditch, and their position is such as to suggest that some significance was attached to the points at which they stand. Farther round the circle of Aubrey Holes to the southward from the southeast stone there is a circular earthwork described as the "South Barrow." A similar earthwork

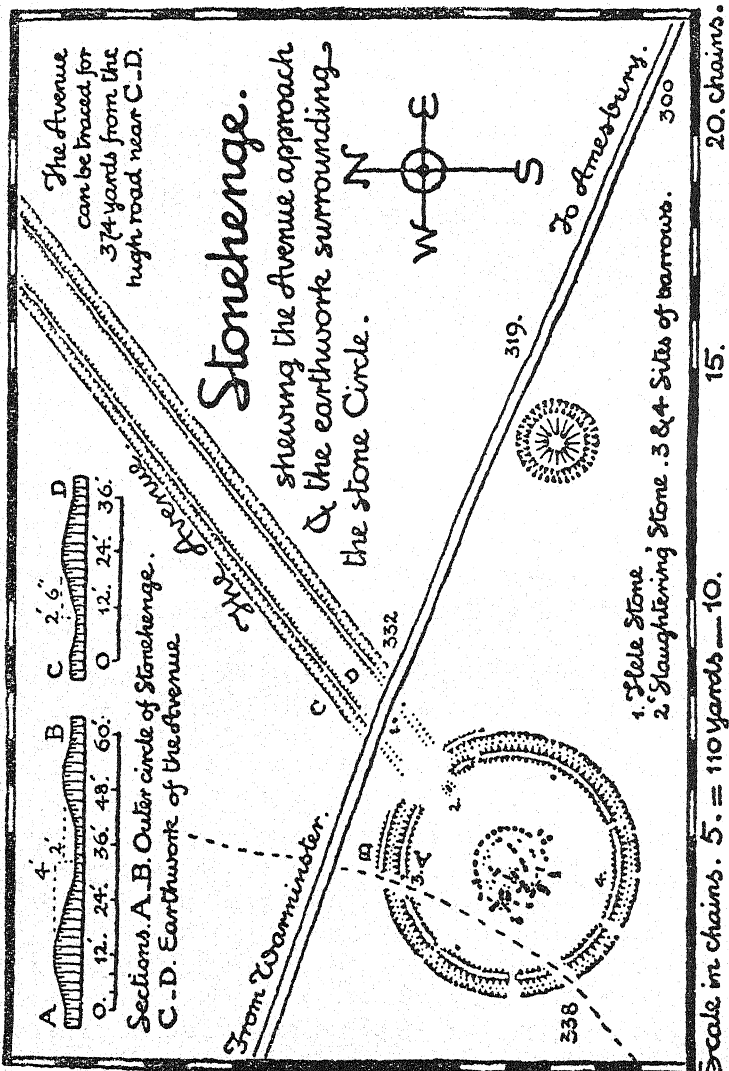


FIGURE 5.

appears on the north of the northwest stone. A line between the two stones passes directly through the center of the circle. In the same way a line between the centers of the two earthworks does the same thing. In addition to this, the distance between each stone and earth-

work is the same, so that the arrangement of these four points is symmetrical. For this reason they are sometimes called the "Four Stations." But though they are thus placed, so that both stones and earthworks are in line with the center of the circle, the view between them is completely blocked by the rest of the monument. To obtain that line, therefore, it would seem that these four stations must have been set out before the circle was erected, and therefore at an earlier date.

Colonel Hawley's excavations have shed further light upon this question, for on investigating the "South Barrow" he discovered it to be a circular ditch surrounding a hole which had formerly held a stone.

With regard to the corresponding "North Barrow," Colt Hoare mentions that there was a circular ditch also, so that it is more than likely that there was also a stone.

Consequently the "Four Stations" originally were four stones, set up with considerable accuracy, the lines joining them meeting at an angle of 45 degrees.

Sir Norman Lockyer has recorded that these stones seen from the center of the circle would indicate sunset and sunrise on May 6 and November 8, February 2 and August 5.

THE SLAUGHTER STONE

This name is apt to be misleading and to suggest rather gruesome rites and ceremonies, of which there is no evidence. The name was given to it by Stukeley in the seventeenth century. It is almost buried in a depression in the ground and lies just inside the Ditch, a little to the south of the axis of the monument.

Opposite to this stone, at the same distance from the center, a large hole was uncovered, which contained a Sarsen packing block, which suggests that there was a second stone which has disappeared. In 1655 Inigo Jones mentioned a pair of standing stones, of which he gives the dimensions, which correspond to those of the existing Slaughter Stone. So that there is every reason to suppose that two stones stood, one on either side of the axis, on the northeast, and that possibly there may have been a lintel stone froming a complete Trilithon.

THE Y AND Z HOLES

Outside the stone circle are two irregular circles of holes, called the Y and Z holes. Only 15 of each have been excavated, but soundings have revealed the existence of 30 in each circle. They have not been marked on the ground, as have the Aubrey Holes. Each pair of Y

and Z holes lies immediately behind each of the Sarsen uprights of the circle.

It is known that they were dug after the erection of the uprights in the circle, because in one case the hole has been dug through the incline used in the erection of the upright. But the irregularity of the circles is most striking. They entirely lack the precision of the setting out of the stone circle. The holes are 3 feet deep and between 1½ to 2 feet wide at the bottom. Can they by any chance have been "constructional" and in some way connected with the raising of the lintel stones? At the moment no definite suggestion has been made as to their use.

THE CIRCLES AND HORSESHOES OF STONEHENGE

After this review of the earthworks and stones outside the circle, the central monument now claims attention.

It begins with the outer circle of Trilithons, which are all of the local Sarsen stone already described. Many of the stones have fallen, but a very fair idea of what the circle was like when complete may be obtained by looking at the group of Trilithons standing between the Altar Stone and the Friar's Heel. The original number of the uprights was 30, and the average weight of each would have been 26 tons. Nine of these have fallen, and five have disappeared. They were very accurately arranged in a perfect circle at equal distances apart, and stood 13½ feet above the ground level. On the top of them was a continuous row of lintel stones, two lintels resting on each upright. These are somewhat smaller than the uprights, averaging 10½ feet in length and weighing rather under 7 tons.

A feature of these lintel stones, not generally noticed, is that they are not perfectly rectangular blocks, for the inner face has been carefully dressed to the curve of the circumference of the circle, a work demanding considerable skill.

This arrangement of lintel stones is most uncommon, and, so far as our knowledge of stone circles in Britain is concerned, is unique.

But there is yet another feature which calls for comment, and that is the way in which the lintel stones are secured to the uprights by a series of mortise and tenon joints, and to one another by toggle joints. The uprights of the outer circle have each two tenons on their summit, one near each end, and the lintels have corresponding sockets or mortises which fit over them. The dressing of these must have been a delicate matter. The toggle joints on the lintels consisted of a groove at one end of the stone and a projection on the other. Colonel Hawley, who had actual experience of lifting and replacing more than one of these lintels, is of opinion that the tops of the uprights were dressed after they were erected. Owing to their

relative position, and careful fitting together, the undersides of the lintels and the tops of the uprights have not suffered from weathering, and in replacing the lintels Colonel Hawley says the joints fitted so well "as to make it difficult to return the lintels to their former places."

Within this circle of Sarsen Trilithons lies a concentric circle of Prescelly uprights of about 78 feet in diameter. This circle has suffered considerable from depredation by farmers and others in search of convenient building stone in the seventeenth and eighteenth centuries. Today only 18 stones remain, but it has been generally accepted that the original number must have been about 40, and some writers have suggested that they numbered 60. The method of their destruction has made it difficult to distinguish the holes from which they were wrenched, for a continuous trench was dug between some of the stones in order to loosen them. Colonel Hawley, from personal examination, is of opinion that the stones were formerly only about 18 inches apart. In some places only the stumps of them remain.

The stones of the inner circle of uprights are between 9 and 10 feet in length and about 2½ feet in width.

Within the two circles just described stands a horseshoe of five detached Trilithons, graduated in height from 16½ feet to 17 feet 9 inches for the first two pairs and 22 feet for the "Great Trilithon" in the center. Two of these five Trilithons are still standing and are certainly the most impressive features of the monument. The central Trilithon is said to have fallen in the year 1620 when the Duke of Buckingham was seeking buried gold at Stonehenge. When this fall took place, one of the uprights cracked into two pieces and the other was dragged forward into a leaning position, in which condition it remained till 1901, when it was restored to its former vertical state.

The next Trilithon, on the north, fell on January 3, 1797, after a sudden thaw, the fall being due in some measure to a shelter dug at the foot of the stones by gypsies.

Of the fifth and last of the Trilithons in the horseshoe, two uprights, one fallen and one erect, remain.

These Trilithons are well worthy of close examination; first, because of their size, for, with the exception of some of the stones at Avebury, they are the largest monoliths in England; secondly, because it is possible to see in them, more clearly than in any other of the stones at Stonehenge, the fitting of the mortise and tenon joints. The standing upright of the Great Trilithon shows on its summit a very perfect example of the tenon, while the fallen lintel which lies at its foot displays the two mortise holes very perfectly.

The Great Trilithon was carefully examined in 1901 by Professor Gowland, who was in charge of the excavations. Two very special Sarsen boulders must have been required for a Trilithon 22 feet high.

One stone 30 feet in length and weighing about 50 tons was forthcoming, but the companion stone was only 25 feet long. In order, therefore, that the crowns of these two uprights should be level, the longer stone had to be embedded 9 feet in the ground, while the shorter one had only a depth of 5 feet. To give it rather more solidity, a boss of

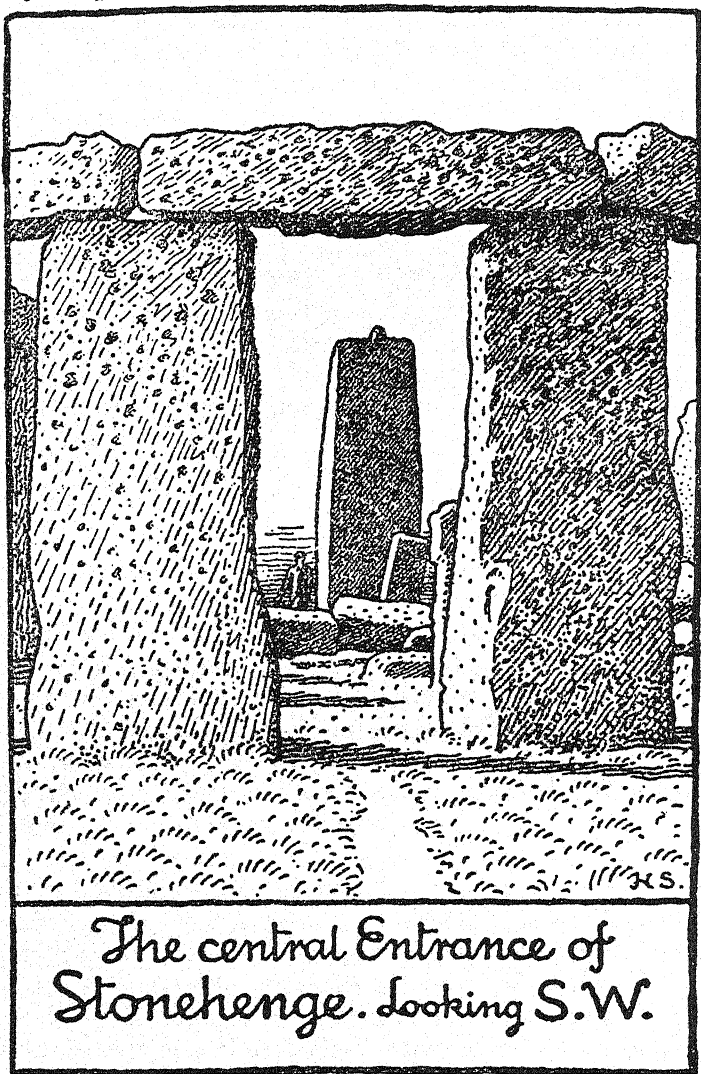


FIGURE 6.

untrimmed stone was left at the base. In the same way the depth of the foundation of all the Sarsen uprights in Stonehenge has been adjusted to meet the length of each stone. The lintel stones of these large Trilithons are of an average length of 16 feet; they are wider on the upper surface than below, and their inner face follows the curve

of the horseshoe in the same way as those of the inner ring follow the line of the circle.

Just as the outer circle of Sarsen Trilithons enclosed a circle of Prescelly uprights, so too does the horseshoe of Sarsen Trilithons enclose an inner horseshoe of Prescelly uprights. These uprights are from 6 to 8 feet in height, and when the horseshoe was complete would have numbered 19; actually there are, including stumps, 12 remaining today. These stones have evidently been specially selected for their unusual length.

Last of all, almost buried beneath the broken upright of the Great Trilithon, comes that stone on which Inigo Jones unfortunately bestowed the name "Altar Stone" in the seventeenth century, and in so doing left the monument with a heritage of sacrificial rites from which it is difficult now to dissociate it. The name certainly rests on no sure foundation of any ascertained fact.

But putting aside altogether any question of sacrifice, human or otherwise, the stone is of special interest. To begin with it is foreign to Wiltshire, and the balance of opinion tends to its having come from Milford Haven in Pembrokeshire, as has already been stated. In addition it is the largest of all the foreign stones at Stonehenge, for it is 16 feet long, 3 feet 4 inches wide, and 1 foot 9 inches thick. Its position is nearly central to the line of the axis, and it may possibly have been somewhat shifted by the fall of the Great Trilithon in 1620. The suggestion has been made that it was once upright, and that it marked a burial. Such things do exist in other circles, whereas flat stones in circles do not exist elsewhere. But Stonehenge is unlike other circles in so many particulars that it is not altogether safe to accept this argument by analogy without further evidence. If the stone were an upright, it would naturally follow that it must have stood in a hole in the chalk, as do all the uprights. Unluckily the site of the stone has been very much disturbed. Stukeley, in 1723, conducted explorations there, and so did William Cunnington in the early nineteenth century, who certainly found a hole in which it may have stood, and about a hundred years later Professor Gowland found traces of excavation about the still upright stone of the Great Trilithon. If the so-called Altar Stone had actually been upright, it would have stood most probably on the axis of the monument, and there seems very little evidence of any definite stone hole. So that, for want of more convincing evidence, it would seem quite reasonable to accept the present position of the stone as being that in which it was originally placed.

THE BUILDING OF STONEHENGE

THE TRANSPORT OF THE PRESCELLY STONES

Hitherto the actual plan and disposition of the stones and earthworks has been dealt with. At this point it may be well to consider the present state of our knowledge of the actual methods employed in dealing with these vast blocks of stone.

One of the first questions which is bound to arise is, Why were the Prescelly stones brought to Salisbury Plain, which is 180 miles from the site where they are found naturally? It should be remembered that there are eight stone circles at Prescelly, as well as many other traces of the Megalithic builders. Consequently a very reasonable suggestion might be that a race migrating from Prescelly would bring their sacred stones with them. The strong stimulus of religion might make such a thing possible. It is practically certain that the stones,

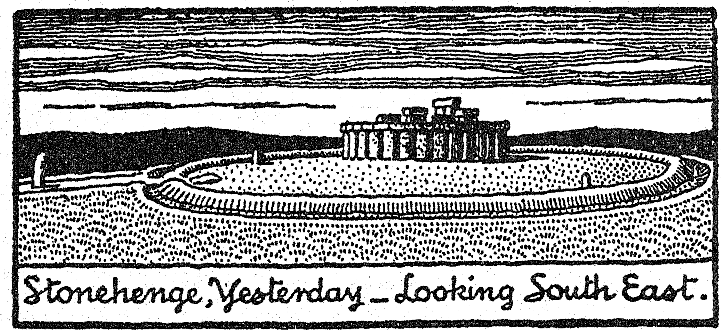


FIGURE 7.

when removed from Prescelly, had not been dressed. This is evident from the large number of chippings found at Stonehenge.

The second question is, How were the stones transported? To this no certain reply can be given. There are three possible suggestions: (1) There may have been an all-land route through South Wales; (2) an all-water route by river and sea, round by Land's End and up the Avon; or (3) a combination of the land and water route using the land to reach a convenient estuary from which the stones might have been shipped.

And here the importance of the material composing the Altar Stone is very evident. If Dr. Thomas' opinion is correct and the stone came from the Cosheston Beds near Milford Haven, the stones must have been moved southward from the Prescelly Mountains. Here, it is true, there are river valleys, but they are quite unsuited for water transit, being swift-flowing mountain streams, with shallows and rapids, which must have presented considerable obstacles for navigation.

On the other hand, there are three ancient trackways recently described by W. F. Grimes, of the National Museum of Wales, which appear to afford a solution as to how the stones came from the mountains to the coast. The first of these trackways, called "Fleming's Way," follows east and west the line of the Prescelly range. From it, leading southward from the range, are two "spur ways"—that on the west leading to Haverfordwest and that on the east to Narberth. Both these spur ways are in use as roads at the present day. Haverfordwest stands at the head of the tidal estuary of the Western Cleddau and Narberth is similarly placed on the estuary of the Eastern Cleddau. The roads have all the features of ancient tracks; they avoid valleys, and their gradients are easy; and in the case of the Narberth road in particular, antiquities are plentiful on the route, showing that the district has been occupied since early times. From either of the two tidal estuaries the waterway leads through the area of the micaceous sandstone of the Cosheston Beds and finally to the sea at Milford Haven.

An interesting sidelight on the date of the removal of the stones from Prescelly is the large block of Prescelly Stone from the Long Barrow, called "Boles Barrow," near Heytesbury, 14 miles west of Salisbury. This was unearthed by William Cunnington in 1801, and after some migrations has at last found a home in the Salisbury Museum. The presence of this stone in a Long Barrow would justify a date of about 1800 B. C. for its transportation.

The stone axes and axhammers of "spotted dolerite" and other rocks from North Pembrokeshire, which have been found not only in Wales but beyond its borders, constitute evidence of human activity in the Prescelly area in Neolithic and Early Bronze Age times.

THE SARSEN STONES

There seems to be little doubt that the Sarsen stones were first of all roughly hewn into shape before they were conveyed to Stonehenge. Among the chippings and mason's waste discovered in the course of excavation, there is comparatively little Sarsen stone, and that usually in large fragments. Also the natural tabular form of the stone adapted itself to the needs of the builders; it was almost an ideal material.

The transport of the Sarsen blocks must have called for considerable skill owing to their weight, one block weighing certainly 50 tons. Even with abundant labor, time in which to transport the stones, and the stimulus of religion, the achievement is a very notable one, and only second to the erection of the stones at Avebury. But the transport of monoliths and monolithic figures was common in other countries, and specially in Egypt, where, prior to Stonehenge

by a thousand or more years, huge figures cut from single blocks of stone were dragged upon a kind of sledge over ground which was freely watered to make the figure skid forward when hauled by ropes.

The final skilled work of dressing was completed on the site. It is impossible today to detect the rough tooling on the exposed surface of the Sarsens. Time and weather have played their part in obliterating it, but underneath the ground, where the bases of the stones have been protected by the earth, the toolmarks are as clear and sharp as when the stone left the craftsman's hands some 4,000 years ago. In the process of straightening the upright of the Great Trilithon in 1901, a thin slab of the surface of the stone became detached. A portion of this slab is in the Salisbury Museum and shows the toolmarks very plainly.

Very considerable skill would have been called for in the cutting of the tenons and making of the mortise holes.

In the case of the outer circle, each upright would have had two tenons; the uprights of the horseshoe on the other hand would have had only one. Still more difficult would have been the cutting of the toggle joints and their subsequent adjustment. This can only have been carried out after the lintels were raised and placed upon the uprights.

The tools used appear at first sight to be of the roughest description. Some are of flint and some of compact Sarsen, but so far no trace of any metal tool has been discovered. Most striking of all are the large mauls of Sarsen, which range between 36 and 67 pounds in weight. Some of these are roughly spherical, others have a broad flat base. Some of them may have been slung on a rope with two ends which could have been swung by two men to give a crushing blow. The spherical stones might very well also have been used to grind the mortise holes with sand and water, a common practice among stone-using peoples. There are likewise smaller Sarsen hammers ranging from 1 to 6 pounds, also roughly spherical, and flint hammer stones which show extensive bruising due to use. Apart from these there are axes and hammer axes of flint. From the excavation at the Great Trilithon alone, over 120 tools were recovered.

Digging the foundation holes was carried out with picks made from the antler of the red deer, very many of which have been found. The usual method was to utilize the first branch or "brow tine" as a pick, and to cut off the rest. Many splinters of these picks have been found embedded in the chalk of the foundations, as well as unmistakable pick holes in the chalk. The antlers were many of them very much larger than those of the present-day red deer. Some are shed antlers, and others have been taken from animals killed in the chase and retain their horn cores.

THE ERECTION OF THE STONES

It must first of all be understood that the setting-out of Stonehenge was done with great care. The Outer Sarsen Trilithons were erected in a perfect circle. The uprights are very evenly placed, 4 feet between each, or to put it in another way, the center of each upright is 10 feet 2 inches from its neighbor, with the exception of the two uprights on either side of the axis (stones Nos. 30 and 1), which are 1 foot farther apart than all the others. This extra width is adjusted by shortening the distance between stones Nos. 29 and 30 and 1 and 2 by 6 inches.

To insure this accurate placing of the uprights, holes were dug which afforded room on all sides for the correct placing of the stone which, once in position, was secured by packing blocks; some of these are from Chilmark, about 13 miles distant. An incline led to the hole in all but two cases, down which the stone was slid. The depth of the hole would, of course, depend upon the length of the upright. At the bottom of each hole which has been examined was a row of holes in the ground, sometimes 6 inches in diameter, which seem to indicate that they were used for wooden stakes which were intended to steady the upright while the packing blocks were being built around the three other sides. Or again these holes may have been for posts used as a fulcrum for a lever. Most probably the holes were used for both purposes; and it is a fact that decayed wood has been found in them, which must have been inserted by human agency. And here it may be noted that very many of the uprights which have been uncovered in excavation have the appearance of having been brought down at the base to a rude chisel edge, which would make the process of shifting forward or backward, or from side to side, much easier than a blunt end to the stone.

But granted the ingenuity of the builders, their care and exactitude in setting out, the vast bulk of the stones weighing anything between 20 and 50 tons, still presents a staggering problem. It is not so much one of manpower, important as this must have been, as of careful thought and direction, and the utilization of simple mechanical principles, which, deftly applied, produced this astonishing result. What kind of ropes were used, for example? It is improbable that hemp was grown and manufactured at that date. Were these ropes of plaited hide? The presence of so many antlers used as picks suggests an abundance of such material.

The Trilithons of the horseshoe, unlike those of the circle, were erected from the inside. This was discovered in 1901, and the important fact followed that the Prescelly stones were erected after the Trilithons.

Nor can the placing of the lintels be taken lightly, apart from the meticulous care expended on fitting them together. Many suggestions have been made, such as levers and alternate packing baulks of timber, or inclines of chalk up which the stone could be rolled.

Stonehenge. Looking N.E. from the altar stone towards the hele stone.

FIGURE 8.

There seems, however, as yet to be little certainty on this subject and very little proof of the methods employed. This is one of the points which will doubtless be solved in time, and it is best, for the moment, not to add to the many speculations already current on the

subject. It speaks well for the care of the builders that the stones should have stood as well as they have done. Of the Sarsens, 16 are standing in the outer circle and 6 in the horseshoe, 13 have fallen or have been moved, and 5 are missing. An examination of prints and drawings reveals the fact that Nos. 13 and 14 were standing in 1574, but No. 14 fell about 20 years later; the big detached Trilithon of the horseshoe fell in January 1797, and No. 22 in December 1900. The fallen lintels, being smaller and ready to hand for removal, are nearly all missing. The Prescelly stones, as has already been said, have suffered more heavily by reason of the ease with which they could have been removed. The relic hunter has also been accused of damage. It is even said that a hammer was kept in a well-known hotel in Salisbury for the use of visitors to Stonehenge. Besides this there was a superstition which endowed the "Bluestones" with medicinal properties, which may also have contributed to their destruction.

OBJECTS DISCOVERED AT STONEHENGE

So far, only the actual implements employed in the building of Stonehenge have been mentioned, but they by no means exhaust the list of objects found in the areas excavated between 1920–28. Very careful investigations have taken place in the Ditch, the Aubrey Holes, the "South Barrow," the area between the outer Sarsens and the Aubrey Holes, the Y and Z holes, and the sockets of stones 1, 2, 6, 7, 8, 9, 29, and 30.

The following list gives a comprehensive idea of the relics:

DITCH

1. From the earth above the chalk silt.—Fragments of Beaker pottery, c. 1800 B. C. (two distinct beakers can be recognized), small Late Bronze awl, c. 500 B. C. (the only actual Bronze Age implement yet found), tanged and barbed flint arrowhead, Roman brooch and coins, "Samian ware," spindle whorls, and two medieval iron arrowheads.

2. From the earthy rubble above the chalk silt.—Implements of Prescelly stone, some partly polished axes, and a small well-wrought stone ball of unknown use.

3. In the chalk silt at the bottom.—Many rough flint implements with deep white stain or patina, a bone chisel, and fragments of chalk balls. Many antlers of the red deer, some cut down to form picks, and others which show signs of use as rakes.

THE AUBREY HOLES

Among the finds were "fabricators" of flint, used in the manufacture of flint implements, and flint flakes; some of these have been replaced upon the cores from which they have been struck off, showing that the work was done on the spot. Besides these there were axes and hammers of Prescelly stone, and fragments of Bronze Age pottery. One of these is of special interest; it is a portion of a vessel with perforated lugs which may have been an "incense cup" of the Middle Bronze Age.

CREMATIONS AROUND THE AUBREY HOLES

Bone pins, well finished, some bearing traces of fire, and a beautifully finished perforated Bronze Age macehead, in hornblendic gneiss, a stone foreign to the district but found in Brittany and also in Scotland. This shows no trace of wear and might, therefore, have been "ceremonial."

GROUND BETWEEN THE OUTER SARSENS AND AUBREY HOLES

Roughly chipped flint implements, Bronze Age pottery, Early Iron Age pottery (c. 400 B. C.), pottery "counter" or disk for playing some game, three Roman coins, Roman fibula (A. D. 350–400), Roman toilet article, Anglo-Saxon silver belt ornament, coin of Ethelred II, minted in London, Norman harness ornament, a groat of Henry II, cut to make a halfgroat, and small bell pendant, possibly from a horse trapping.

Y AND Z HOLES

Rough flint implements, small tablets of Prescelly stone, perhaps "counters," Prescelly axhammers, Bronze Age pottery, Early Iron Age pottery, Roman New Forest ware, "mock" Samian, made locally, fragment of Roman brooch, bangle, and three Roman coins.

SARSEN STONE HOLES

Flint implements (two scrapers with polished edges, fabricator, etc.), tablet and implements of Prescelly stone, broken perforated hammer (not Prescelly stone), Beaker pottery, Early Iron Age pottery, Roman pottery, part of Roman bronze bracelet, and a hone.

AREA AT OPEN END OF HORSESHOE

Fint implements (scraper with polished edge), Beaker pottery, bone pin, Early Iron Age pottery.

"SOUTH BARROW"

Deer antler pick, flint hammer, adz and scraper, parts of three Prescelly stone axes, portion of the cutting edge of perforated axhammer.

On reviewing the above discoveries, from every part of the southeastern half of Stonehenge, it will be at once noticed that flints, Prescelly axes and hammers, and Beaker pottery are widely distributed and a normal result of excavation. More special and of equal importance are the Middle Bronze Age "incense cup" and the perforated ax from the Aubrey Hole cremation. The predominance of the tools of Prescelly stone seems to indicate that they belong to a time when those stones were dressed and when Stonehenge was erected. The greater number of the discoveries lie between the late Neolithic and the Early Iron Age. There is a very considerable amount of Beaker pottery and a certain number of later Bronze Age objects, but they are not very plentiful. The same may be said for the Early Iron Age remains. Roman, Saxon, and other objects seem to have no bearing upon the date of the monument.

The flint and stone implements are found throughout the excavations at all depths, and even under the foundation of one of the Prescelly stones. Further antler picks, similar to those used at Stonehenge, have been found in the Beaker flint mines at Easton Down, not many miles from Stonehenge, where they were used to win flint for the manufacture of implements which are identical in their working with those found at Stonehenge. The Easton Down Settlement throws an important sidelight on Stonehenge, since it yields not only flints and Beaker fragments, but also pottery of the earliest known type known as Windmill Hill pottery, which can be dated as about 2000 B. C. The similarity, therefore, between the Stonehenge tools and those in use at Easton Down, to which a period has been assigned, indicates that the date of the building of Stonehenge may fairly be placed at a time when the use of stone was contemporary with a partial use of bronze, and that, if Stonehenge is not a late Neolithic structure, it must certainly belong to the Early Bronze period.

It may be urged that the roughness of the tools and the almost complete absence of bronze would indicate an even earlier period. It should, however, be remembered that the form of the tool is governed very largely by the work it is called upon to perform. Bronze tools would have been useless to deal with the compact stones at Stonehenge. The crushing weight of a heavy maul or stone hammer ax would have been more effective than a light bronze tool, which would be liable to bend or buckle.

To many people the mention of a culture period may not convey very much. To give a date in actual years is by no means easy. The march of culture in those distant times was slow and liable to be arrested from time to time. The passage from the use of one material to another was prolonged, often reaching into centuries. Speaking very generally, it may be said that the Megalithic culture reached the west of England and Wales about 2500 B. C. and that it was followed by the Bronze Age culture, on the east and south coasts of Britain about 2000 B. C.

WHO BUILT STONEHENGE?

So far nothing has been said as to the race or races which built Stonehenge, beyond the fact that two races are recognizable in the structure of the stones and the objects which have come to light in the course of excavation. This subject opens up rather a wider field of inquiry than that hitherto pursued. It is necessary now to survey the continent of Europe, and to study the distribution of the Megalithic Builders and their successors, the Early Bronze Age or Beaker Folk as they are generally known.

Sir Cyril Fox in his "Personality of Britain" furnishes the requisite material in his wonderfully suggestive maps of Megalithic and Beaker distribution in this country, as well as in his map of Europe showing the approach of these races to Britain. He shows very clearly that the Megalithic monuments of the late Neolithic Age are concentrated in the south, west, and north of the island, while the Beaker Folk can be located as certainly in the east and south. But as he points out, "the only intensive overlap is in the south of Britain—the Salisbury Plain region." Let us consider the Megalithic people first of all. Their monuments (long barrows, chambered cairns and dolmens) follow the Atlantic coast of Portugal, Spain, and France, notably of course at Carnac in Brittany. The first landfall of Britain from that district is round and about Land's End, with its very numerous and convenient harbors and estuaries, whence it would be easy to pass up the Irish Sea to the Hebrides. This contention is fully supported by the distribution of their monuments in Cornwall, South Wales, and up the deepwater channel northward to the Hebrides. With this western sea route open to the primitive shipmen, Britain was in the stream of European culture, and in all probability western Britain was living in a higher standard of culture than eastern Britain.

There would seem to be very little doubt as to the origin of the Prescelly stones at Stonehenge, but the actual route by which they were transported seems as yet a matter of conjecture rather than proof. The question may be asked, Why were they ever carried such

a long distance to Salisbury Plain? This may best be answered by a consideration of the map of Britain at that remote period. Dr. Fox conveniently divides the islands into the Highland and Lowland areas; the division is a rough one but most suggestive. He points out the natural barriers imposed by the Cambrian Mountains, Exmoor, Dartmoor, and the Cotswold and Mendip Hills, which shut off the Lowland zone of the Western Downs and Salisbury Plain from the Pembrokeshire Megalithic center.

The Lowland zone had its strong attraction, with rolling downs offering good pasture, and its deep estuaries to the sea; but there was in the Lowlands no stone for Megalithic monuments except limestone, and the Sarsens which have been used to great purpose at both Stonehenge and Avebury. When it came to final settlement, the Megalithic Race were more attracted by the chalk downs of Salisbury Plain and the limestones of the Cotswolds and Mendips than by the rocky land of Devon and Cornwall with its barren moors. The Lowland always had its attraction for the early migrants, its easy contours offered no obstacle. The newcomer had a better chance of settlement than in a difficult mountainous country. Granted that the Salisbury Plain area offered a definite attraction, it would hardly strain the bounds of possibility to suppose that a tribe or clan, making the long journey to what was to them a Land of Promise, would take their Stone Circle with them, and erect it on their arrival, as an almost sacramental act of taking possession of the land. Such a supposition would account for a circle of unhewn Prescelly stones on Salisbury Plain.

But the tide of immigration to Britain was flowing fast, and within about 500 years of the arrival of the Megalithic Race by the Atlantic route, a new race, known as the Beaker Folk, were arriving on the eastern and southern shores of Britain. The race appears to have moved westward to these islands from the Rhinelands, the breeding ground of those cultures which have affected eastern Britain at all times. Probably in the case of the Beaker Folk, some took a northerly course down the Rhine, and others a westerly one by way of the Seine or Somme, arriving at the southern estuaries in Britain and spreading inland.

Why were these people called the Beaker Folk? Wherever they penetrated into this country they made of the local clay vessels known as "beakers" or "drinking cups." These are probably the most widely distributed of any prehistoric pottery. Beakers vary in shape, but can be divided into classes according to their form. Two forms can be recognized in Wiltshire, type A and type B, both of which occur at Stonehenge. It is generally thought that type A comes from the east coast migrants, and type B from the south coast.

It is very significant that both type A and type B have been found at Stonehenge, showing an overlap of the two migrations there.

The position, therefore, at Stonehenge seems to be that there certainly was a race of Megalithic Builders who brought stones from Wales, but that, at about the same time, or rather later, there was also an infiltration of Beaker Folk from the east or south coasts, or from both. These last people are known to be a very vigorous race which spread over the greater part of Europe. They already had a knowledge of bronze. It seems most likely that the Megalithic and Beaker people mingled together quite peacefully at Stonehenge, and it would be quite possible that the special features in construction of Stonehenge, which differ from those of Megalithic circles generally, would be due to the fresh influence of the Beaker Folk working on Megalithic tradition.

THE BARROWS ROUND STONEHENGE

It is impossible to visit Stonehenge without passing numbers of burial mounds or Barrows, some singly, some in clusters. In the immediate neighborhood of Stonehenge there are two Long Barrows and about 300 Round ones. This can hardly be accidental; rather would it appear that the Barrows reached their highest development on Salisbury Plain and the Stonehenge region, and form a vast necropolis about the circle. That there are few Long Barrows is due to the fact that they were probably earlier than the circle. That there are roughly 300 Round Barrows of all kinds, would justify the assumption that the sanctity of the site made the spot specially attractive for burial.

THE LONG BARROWS

This is the older form of burial mound, and may generally be referred to the Neolithic period. They are usually found standing alone, and very often on rising ground. They vary from 200 to 400 feet in length, 30 to 50 feet in breadth, and 3 to 12 feet in height. The heaped-up earth and chalk of which they are composed was dug from a trench on either side of the mound. The trench, however, did not continue round the two ends of the Barrow. They lie usually, but not always, east and west, and the eastern end is higher than the western. The sepulchral deposit is generally in the higher end of the Barrow. No metal objects have been found in these Barrows, though delicately chipped leaf-shaped flint implements are almost invariably met with, and occasionally very rough hand-made pottery of early type.

THE ROUND BARROWS

These may be roughly divided into three main groups:

(1) The Bowl Barrow, most frequently encountered, having a diameter of from 20 to 60 feet, and a height of 3 to 5 feet.

(2) The Bell Barrow, which reaches its highest development on Salisbury Plain, and is more generally found in Wiltshire, and particularly round Stonehenge, than in any other part of England. It is entirely surrounded by a circular ditch, from which the material of the mound has been dug; within the ditch is a circular area level with the turf, from which the mound rises from 5 to 15 feet in a graceful conical form. The diameter will be upward of a hundred feet, so that the entire structure is larger and more impressive than a Bowl Barrow.

(3) The Disk Barrow resembles the Bell Barrow, since it too is surrounded by a ditch, but instead of the conical mound in the center, it has one or even two or three small mounds, or "tumps," in the center in which cremated remains are found. The Disk Barrows are not so numerous as the Bowl-shaped Barrows, but there are roughly twice as many Disk Barrows as there are Bell Barrows in Wiltshire.

These figures are only a rough indication of the relative numbers of the two last types of Barrow, for it must be remembered that, particularly in the case of Disk Barrows, there is a tendency for them to disappear in the course of time, while the needs of the farmer have often led to their being plowed down altogether.

The contents of the Barrows are also of importance as regards Stonehenge, for they shed some light upon the people buried within them.

In the Bowl Barrows skeletons are usually found buried in a crouching position, with the knees drawn up to the trunk and the legs bent on the thighs, the arms closed toward the chest and the hands over the face. The bodies lie generally with the head to the north, but not always.

In Bell Barrows the crouched skeleton is found as before, but cremated human remains also occur enclosed in hand-made pottery urns, which were sometimes inverted and often protected by a cist of rough flints.

Almost without exception the Disk Barrows contain only cremated remains. In most cases cremation would seem to have taken place elsewhere and the remains then carried to the place of burial. Cremations appear to be more frequent than inhumations, and are considered to be of a later date.

Cinerary urns vary in size considerably, from 9 to 15 inches in height, and from about a pint to a bushel in capacity. The well-known "Stonehenge Urn" at the Devizes Museum is a magnificent example, 22 inches high, while an even larger one, 24 inches in height, is in the

Salisbury Museum. These hand-made vessels are very remarkable examples of primitive potting. Though showing no trace of the potter's wheel, they are beautifully symmetrical. The body consists of a mixture of clay with very fine pebbles, pounded flint, and sometimes chalk or shells. For finer work sharp sand has been used. The firing is often imperfect. The decoration is simple, usually consisting of lines or dots, often applied chevronwise, but in the later examples less care seems to have been shown, and the ornament degenerates into lines of thumb marks. At its best period, the cinerary urn was decorated with very clever designs made by the impress of twisted cords, and in still earlier forms, by the use of a comb of points which gave the fine dotted lines found upon the early beakers. No curves, circles, or animal forms appear at all.

The beaker is always constant in its shape, the cinerary urns vary according to their period, the Middle Bronze Age examples having overhanging rims which disappear in the Late Bronze period.

Then there are globular cups, and the curious perforated vessels called "incense cups," which might possibly have been small braziers for carrying fire; certainly they have all the appearance of a modern censer.

Besides the pottery in the Round Barrows, there are weapons and tools, some of stone, some of bronze, and occasional ornaments of gold, amber, jet, or glassy paste. The presence of these substances used as ornaments suggests the existence of trade in those early days; the gold would have come from Ireland, the amber from the Baltic, and the jet from the north of England. The place of origin of the glassy paste is still a matter of debate.

Though the age is called the Bronze Age, there was a very considerable overlap of stone tools used side by side with the recent metal forms. Stone axes of great beauty, both perforated and unperforated, have been found, but it is significant that the perforated examples are more numerous.

Flint arrowheads when found are always finely barbed. The bronze weapons found are usually of an early type, indicating the erection of the Barrows very shortly after the building of Stonehenge. No other Barrows in Wiltshire have been so productive of bronze daggers as those round Stonehenge. In some cases even the sheaths have been found. The handles were of wood, riveted to the blade, and strengthened occasionally by an oval bone pommel. In one case an elaborate arrangement of gold pins hammered into the wood in a zigzag pattern was found. Personal ornaments of gold have been found in seven Barrows; these consisted of wooden cores, the gold being hammered on and fastened by indentation. Amber ornaments were found in 33 Barrows; the quality of the material was usually

red and transparent, though pale amber has also been found. They are mostly in the form of necklaces, either of beads or graduated plates, strung together.

STONEHENGE AND THE DRUIDS

There is a very persistent story that Stonehenge was connected with the Druids and with human sacrifices. There is, indeed, a considerable literature on the subject and not a few prints depicting Druidical ceremonies at Stonehenge, with blazing fires on the Altar Stone itself. But there are considerable difficulties in accepting the Druid "legend."

The Druids were a Celtic priesthood of whom we have no knowledge before the first century B. C. That being so, it seems very difficult to associate them with a monument which has yielded so much evidence of races at least 1,800 years previous to our first knowledge of their existence. The Druids do not appear in the earliest accounts of Stonehenge.

It was John Aubrey, the antiquary, who first put forward the claim of the Druids, but even this was a very qualified claim, as he himself admits "This enquiry is a groping in the dark." But the idea, once started, did not die, and William Stukeley in the next generation, 1740, working on Aubrey's suggestion, was a whole-hearted champion of the Druid theory. He was obsessed by the Druids. Of all writers on Stonehenge he was more completely successful than any in the propagation of his doctrine, and no one seems to have disputed his conclusions, which were accepted on the Continent, so that the French monuments also became Druidic.

By the early days of the nineteenth century, Stukeley's theory was an article of general belief.

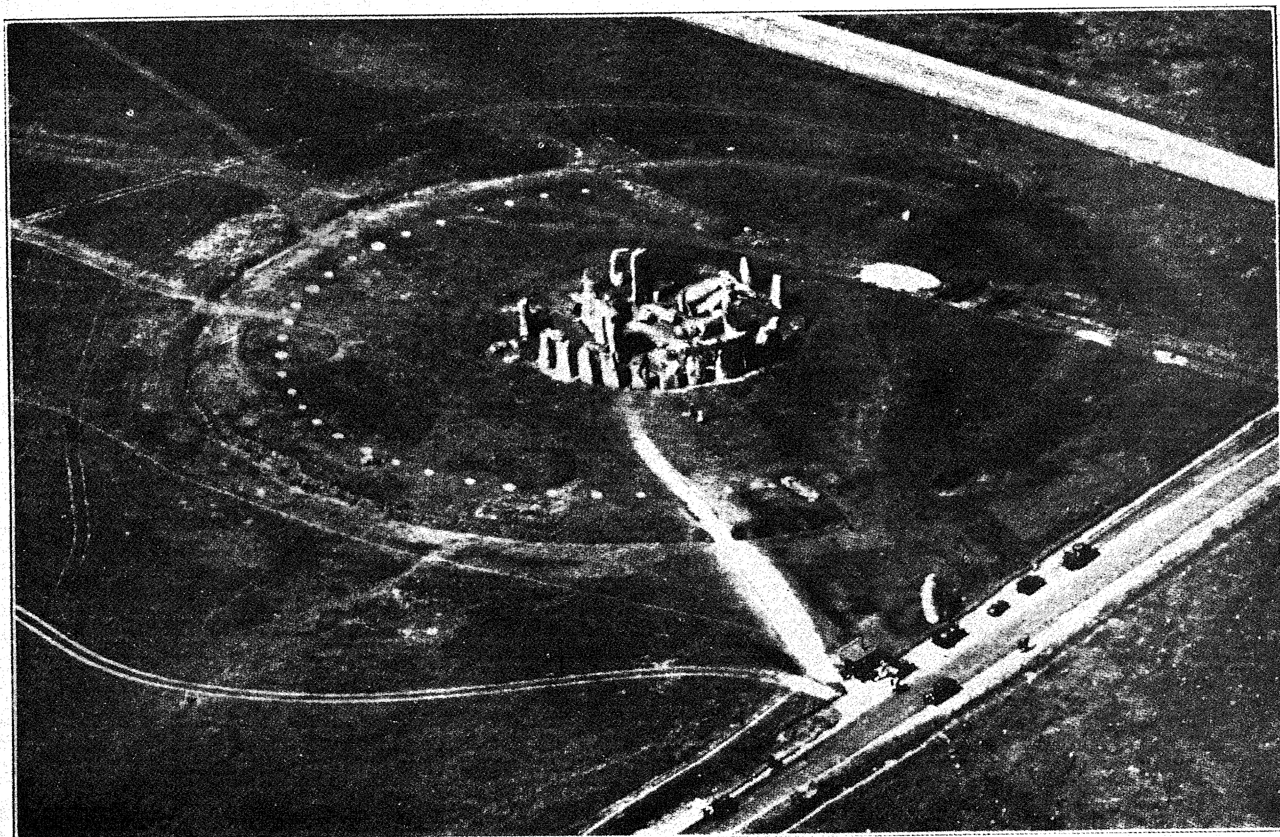
The Druids were a late Celtic priesthood, whom Caesar found established in Gaul in the first century B. C. He was told that they originated in Britain, but the first historical record of them in this country is in Anglesy in the first century A. D. They seem to have continued to exist until about the fourth century, when they disappeared until Stukeley brought them to light 1,300 years later, and provided them with beliefs, knowledge, ritual, and ethics of a singularly picturesque but quite unreliable nature.

CONCLUSION

It has become customary to dismiss Stonehenge as a monument of mystery whose origin will never be solved. Such an attitude of mind is not likely to add to the existing knowledge of Stonehenge. As a matter of fact, it is possible to look back upon a period of some 20 years, during which very material facts have come to light, when

books containing much valuable and suggestive material have been written. That is all to the good. On the other hand, an impatient public demands an immediate and complete solution of every problem offered by the circle. This is the age of hurry and speed, but neither hurry nor speed will avail much in archeological problems, where evidence needs to be weighed with care and deliberation. But sooner or later the so-called mysteries will be revealed to a public which has the patience to wait and to be content with such enlightenment as can be granted to it in the present day.

The last word on Stonehenge has not yet been spoken; the outlook for the future is hopeful. Today the work of excavation is a fine art, undertaken under skilled direction. Experts of all kinds cooperate, each in his own sphere, to see that every fragment of evidence has its fullest importance. The day of conjecture and guesswork is past, and we can look forward with confidence to the future, when, in due course, Stonehenge again comes under the hand of the modern investigator.



STONEHENGE FROM THE AIR.

SULFANILAMIDE AND RELATED CHEMICALS IN THE TREATMENT OF INFECTIOUS DISEASES[1]

By Wesley W. Spink, M. D.
Assistant Professor of Medicine, Minnesota Medical School

Last fall the University of Minnesota Medical School celebrated its fiftieth anniversary. A scientific program was arranged and included addresses by outstanding scientists of this country and Canada. The committee in charge of the program wisely selected a central theme for all the addresses and round table discussions. That theme was "Some Trends in Medical Progress with Particular Reference to Chemistry in Medicine." All the speakers emphasized the tremendous contributions that chemistry has made to all branches of medical pursuit. Tonight it is my purpose to discuss with you one of the most significant advances made in the treatment of human disease. This momentous discovery which has already alleviated untold suffering is a further tribute to the ingenuity of the chemist.

Before unraveling the story of sulfanilamide, it is necessary to review briefly the development of our knowledge concerning infectious diseases. Prof. Hans Zinsser has defined an infectious disease as follows: "When microorganisms gain entrance to the animal or human body and give rise to disease, the process is spoken of as an infection." It was a little more than 50 years ago when this relationship between disease and bacteria was definitely established. It is true that during the fifteenth and sixteenth centuries when syphilis was so common, it was suspected by some that an infectious agent was responsible. But it remained for those intellectual giants of the latter part of the last century to prove that bacteria caused disease. Leaders among these were the French chemist, Louis Pasteur, and the Prussian general practitioner, Robert Koch.

When the causes of infectious diseases became known, efforts were made to control them. One of the methods established was to prevent the organisms from reaching human tissue. Excellent examples of this preventive type of medicine were the control of malaria, yellow

[1] From the Division of Internal Medicine of the University of Minesota Hospital and Medical School. One of the thirteenth annual series of public lectures sponsored by the Minnesota Chapter of the Society of the Sigma Xi. Reprinted by permission from the Sigma Xi Quarterly, vol. 28, No. 2, summer, 1940.

fever, cholera, and typhoid fever. Another method was to prepare the human tissue so that if the bacteria did strike they were defeated from the start. This included vaccinating against smallpox and typhoid fever, and immunizing against diphtheria. Still another means of combatting infectious diseases was made available. If the bacteria had already invaded human tissue and caused disease, through the elaboration of toxins, serum such as antitoxin could be used to shorten the illness. Illustrative of this was the introduction of diphtheria antitoxin into the therapy of diphtheria.

There are many interesting chapters in the annals of medical history concerning attempts to control and combat infectious diseases with chemical compounds. Consider the epoch-making contribution of Joseph Lister, who introduced carbolic acid into the operating room to prevent the contamination of operative wounds by bacteria. For years, it had been common knowledge that certain chemicals would kill microorganisms in large numbers, and do so in a short period of time. Why not then inject these chemical solutions into human beings whose bodies were being ravaged by bacteria? The major difficulty with this procedure has been that these chemicals not only killed the bacteria but destroyed the human cells as well. A definite advancement was made when Paul Erlich and his chemists synthesized an arsenical compound which could be injected into the blood with reasonable safety for the treatment of syphilis. But this was not an accomplishment completed without many disappointments. Although they knew that arsenic spelled death of the spirochete of syphilis, they also knew that this element was very toxic for human tissues. The problem that confronted them was to introduce arsenic in such a chemical combination that it would still be effective against the spirochete and yet not be injurious to the host. After experimenting with many combinations—606 to be exact—they gave arsphenamine to the world. Since then other chemicals have been safely introduced into the human organism for the treatment of infections, such as emetine hydrochloride for amoebic dysentery, and atabrine for malaria.

In discussing the history of sulfanilamide, Schulte has stated, "Sulfanilamide did not appear suddenly, but was the product of numerous investigations which extended over a period of 30 years." Like so many other major scientific discoveries, the successful introduction of sulfanilamide into the treatment of human disease was a summation of the ceaseless work of many individuals. I should like to cite for you a few of the persons whose names are closely linked with one of the most outstanding therapeutic triumphs of our time. Time does not permit us to include everyone.

P. Gelmo, a chemist working with the interest of the German dye industry in mind, was apparently the first one to synthesize para amino benzene sulfonamide. He reported his investigations in 1908. Little did he realize that a quarter of a century later this compound would be known as sulfanilamide, and used in the treatment of human infection.

M. Heidelberger and W. A. Jacobs, two Americans working in the Rockefeller Institute in New York, observed in 1919 that certain azo dyes, including para amino benzene sulfonamide hydrocupreiene would kill bacteria in the test tube. They stated in their paper at the time that their colleague, the late Dr. Martha Wollstein, would extend these observations, but she never did.

F. Mietzsch and J. Klaren, two German chemists working in the I. G. Dye Works in Elberfeld synthesized a red dye called Prontosil, and patented it on December 25, 1932. G. Domagk, the young director of the Institute of Experimental Pathology in the same dye works, observed in 1932 that Prontosil protected mice against fatal doses of hemolytic streptococci. He announced the results of his important investigation in 1935, and at the same time, stated that a closely related chemical compound, Prontosil-Soluble, had similar protective properties.

At this stage certain workers in France became interested in the progress that the Germans had made. Important contributions were made by Levaditi, Vaisman, Fourneau, and Girard. J. Trefouël, Mme. J. Trefouël, F. Nitti, and D. Bovet made a most significant announcement late in 1935 to the effect that the action of Prontosil on microorganisms was due to its being broken down in the body to form sulfanilamide, and that the latter compound was as efficient a therapeutic agent as Prontosil. Their conclusions were based in part upon the observations of Heidelberger and Jacobs.

L. Colebrook and M. Kenny, working in England, demonstrated, in 1936, the value of Prontosil and Prontosil-Soluble in the treatment of puerperal infections.

P. Long, E. Bliss, and E. K. Marshall, Jr., and their associates at Johns Hopkins University, in 1936, confirmed the clinical and experimental findings of the European investigators. This Baltimore group is largely responsible for placing this new form of chemotherapy upon a firm foundation in this country.

The successful clinical application of Prontosil in the therapy of the dreaded streptococcal infections is one of the most spectacular medical triumphs of our generation. Before we knew about Prontosil there was no known specific agent that was of much value in the treatment of this type of infection. Consequently, the mortality rate was high. It should be pointed out that whereas Prontosil has been

extensively used in England and on the continent, it was never introduced for general use in this country. Sulfanilamide has been the drug of choice in the treatment of various diseases due to the hemolytic streptococcus. In evaluating the results of sulfanilamide therapy in this type of infection, it has been observed that the drug has shortened the duration of the disease, prevented complications, and reduced the mortality rate. Following are some of the streptococcal infections for which sulfanilamide has been of value: Puerperal fever, erysipelas and cellulitis, septicemia, scarlet fever, acute otitis media, mastoiditis, meningitis, pneumonia, tonsillitis, and peritonitis.

Puerperal fever is an invasion of the issues by streptococci occurring in mothers at the time of childbirth or shortly thereafter. It is a disease that has been viewed with alarm for many years by the medical profession because it has such a high death rate; it is contagious, often sweeping through a maternity hospital; and specific therapy has been wanting. The investigations of Colebrook in England, and others, have shown that sulfanilamide and its related compounds have lowered the death rate, shortened the duration of the disease, and prevented disabling complications.

Erysipelas and cellulitis, which are streptococcal infections of the skin and their deeper structures, have responded well to sulfanilamide therapy, provided the drug is given early in the course of the disease. These infections often kill patients because the streptococci invade the blood stream. Sulfanilamide not only affects the local lesion, but keeps the blood free of organisms.

Septicemia, or the state wherein streptococci actually reproduce in the circulating blood, has been one of the most feared of all infections. The onset is sometimes insidious, but terminates in a fulminating and often fatal infection. You probably all know of examples where an individual had an innocent appearing lesion, such as a blister which had ruptured, and then streptococci invaded the injured tissue, quickly entered the blood stream, and death resulted. Treatment in most instances has been ineffective. The mortality rate was over 75 percent. Sulfanilamide therapy has cut this rate at least in half, and we may expect even better results in the future.

Scarlet fever, for the most part today, is a mild streptococcal infection, but it may result in serious complications. Convalescent human serum or potent antitoxin obtained from the serum of immunized horses are useful and often adequate in the treatment of scarlet fever. It would appear that the early administration of sulfanilamide may prevent the formation of metastatic bacterial complications. In other words, antitoxin neutralizes the toxin elaborated by the streptococcus, whereas sulfanilamide acts directly upon the organism. Doctors Sako, Dwan, and Platou, working at the Minneapolis General

Hospital, were among the first in this country to show the value of sulfanilamide in the treatment of scarlet fever.

Acute otitis media, an infection of the middle ear which is so common in children, is a dangerous disease. It may cause permanent loss of hearing, mastoid disease, or it may extend to the meninges and brain resulting in a fatal outcome. Sulfanilamide, judiciously administered under the watchful eye of the physician, may often interrupt the progress of the infection and terminate the disease permanently.

Streptococcal meningitis is the most serious of all infections caused by this biological agent. Recovery from this disease was an uncommon occurrence before the present era of chemotherapy. The use of sulfanilamide has been followed by startling results. The mortality rate has been reduced from 98 percent to around 20 percent.

While the results are less dramatic in patients with streptococcal pneumonia and empyema, sulfanilamide is of benefit. Mention should be made of the treatment of acute tonsillitis, and pharyngitis due to the streptococcus. This includes the so-called septic sore throat. Sulfanilamide is of value in those cases where the condition is definitely due to the hemolytic streptococcus. But I would like to emphasize the dangers inherent in administering the drug to every patient who has a sore throat. As shall be pointed out, sulfanilamide and its related compounds often cause severe toxic conditions which may be of more serious consequence than the disease for which it is given.

Although sulfanilamide and its related compounds were introduced primarily for the treatment of streptococcal infections, it was soon observed that other types of infections were favorably affected by their use. Among these other diseases was gonorrhea. It has been estimated that this infection afflicts around a million people a year in this country. It has caused untold suffering and chronic illness in its victims, some of them having acquired the disease through no fault of their own. Treatment has been very unsatisfactory. Because of the social stigma attached to the disease, these patients often ferreted out quacks and pseudo-physicians in an attempt to obtain a cure. One of the good fortunes of this age was the announcement coming from Johns Hopkins University that sulfanilamide would cure gonorrhea. It is now accepted that this compound is a specific therapeutic agent for gonorrhea. One of its outstanding contributions is that the devastating complications that gonorrhea causes, such as crippling arthritis and blindness, are prevented. On the other hand, the drug may have caused a social menace in that infected individuals often take the drug without the advice or jurisdiction of a physician. Lacking laboratory confirmation of a cure, they often have a latent form of the disease, and are capable of transmitting it to others.

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Another serious infectious disease in which sulfanilamide has provoked almost miraculous cures is meningococcal meningitis. Curiously enough, the causative agent, which is the meningococcus, has biological characteristics that are closely related to the gonococcus. It has appeared only logical then to try the drug in the treatment of meningococcal meningitis, and it worked. I have seen a child in deep coma afflicted with the disease, to whom sulfanilamide was administered, and within 72 hours an almost unbelievable transformation in physical well-being occurred. At the end of that time, he was sitting up in bed playing with his toys. Even though we have potent immune serum for the treatment of this disease, sulfanilamide appears to offer the best form of therapy. Whether serum should be used along with sulfanilamide is still an open question.

There are several other diseases that are either cured or favorably influenced by sulfanilamide therapy. Trachoma, which is a painful, chronic infection of the eye often resulting in blindness, has yielded in some instances to sulfanilamide. Many infections of the urinary tract, such as cystitis, and pyelonephritis are permanently cured by this drug. Sulfanilamide is apparently of some merit in the treatment of undulant fever, a disease transmitted to man either directly or indirectly from cattle and hogs. However, we have encountered disappointing results in several patients with undulant fever treated at the University Hospital.

While we can continue to extol the virtues of sulfanilamide, and enumerate other infectious diseases where limited data show that sulfanilamide is a helpful remedy, time does not permit. It should be pointed out that there remains a group of infectious diseases where sulfanilamide is of very doubtful value, and its use in some of these may be actually harmful. They include typhoid fever, paratyphoid fever, staphylococcal infections such as osteomyelitis, carbuncles and boils, acute rheumatic fever, the common cold, epidemic influenza, Rocky Mountain spotted fever, rheumatoid arthritis, and tuberculosis.

It is of interest that the drug has been used as a prophylactic; that is, to prevent disease. I shall mention only two examples. Knowing that children who have had acute rheumatic fever are quite likely to have a recurrence when they contract streptococcal infections, certain well-known physicians have given the drug in small doses to these children to prevent streptococcal sore throats. The results are very promising, but demand further investigation to see if the prolonged administration of the drug to growing children has any harmful effects. Another prophylactic use of sulfanilamide was worked out by the surgeons at the Minneapolis General Hospital. It had been recognized for years that when an individual had a compound fracture with fragments of bone protruding through the skin,

and the wound contaminated by dirt and microorganisms, there was a great danger of infections occurring in the injured tissues. To prevent these infections, these surgeons have placed pure sulfanilamide crystals in the wounds with the results that the incidence of infections following compound fractures has been considerably reduced.

The question is often raised, How does sulfanilamide work? The answer is still shrouded in some mystery, but we can say that the drug acts directly upon the microorganisms interfering with their metabolism. They fail to reproduce as rapidly, and those remaining are injured so that the defense mechanism of the body can cope with and kill them. As a matter of fact, there is some evidence that sulfanilamide may actually kill small numbers of organisms.

Thus far, we have extolled the virtues of sulfanilamide. It must be emphasized again and again that sulfanilamide and its related compounds are potentially dangerous drugs. Their administration to patients may result in serious toxic reactions. Under no circumstances should any individual take any of these drugs unless they are prescribed by a physician. The physician, in turn, must be prepared to observe the patient closely, and withdraw the drug when toxic signs and symptoms manifest themselves. Shortly after sulfanilamide had been accepted by the medical profession of this country, a number of human lives were sacrificed following the ingestion of a preparation known as Elixir of Sulfanilamide. It was discovered that the cause of these deaths was not due to sulfanilamide, but to a constituent of the Elixir, diethylene glycol. In order to prohibit the hasty marketing of new drugs with a repetition of another tragedy, Congress revised the Federal Food and Drug Act. At the present time, new chemotherapeutic agents are made available for the medical profession only after they have been thoroughly investigated as to their toxic properties and therapeutic value.

I would like to discuss now the toxic reactions that are caused by sulfanilamide in the human being. It is well that the patient, the relatives, and physician should have some knowledge of these manifestations. Some of these are more serious than others. Certain of these may cause the patient and those caring for him some alarm, but may not be a contraindication to a continuation of therapy. The first group of toxic manifestations are related to the central nervous system. They are dizziness, headache, mental depression, giddiness, nausea and vomiting, convulsions, and psychoses. Usually, we do not consider the first four serious enough to warrant withdrawal of the drug when the patient is kept in bed. However, the exhibition of dizziness and giddiness may be of serious moment in ambulatory patients who endeavor to carry on their daily work, particularly in those individuals operating motor vehicles, or engaged in dangerous occupations. Bed-

ridden patients may become so disoriented and maniacal, that cessation of drug therapy may be necessary. Nausea and vomiting are usually not severe enough to necessitate suspension of sulfanilamide treatment.

A majority of the patients taking sulfanilamide develop varying degrees of cyanosis of the skin and mucous membranes. This bluish discoloration is due to the conversion of a part of the hemoglobin into methemoglobin, and rarely sulfhemoglobin. Although the morbid appearance of the patient may startle the uninitiated, we do not consider methemoglobinemia a contraindication for further administration of the drug.

A more serious toxic reaction is so-called drug fever. It usually occurs after an individual has taken sulfanilamide for several days. While the patient is receiving sulfanilamide, the temperature may approach normal, and then begin to rise again, sometimes quite high. The problem then confronting the physician is whether this secondary rise in temperature is due to a spread of the infection or due to drug sensitivity. Obviously, the treatment is quite different for each condition. When the fever is due to sulfanilamide, its administration should be discontinued at once. The appearance of drug fever may herald the onset of more serious toxic reactions if therapy is continued. When the drug is omitted, the temperature again approaches normal. We have been impressed by the clinical observation that once a patient has had drug fever, it is likely to occur again when only a single dose of sulfanilamide is given at a future time. This toxic reaction emphasizes again the inherent danger of self-medication without the attendance of a physician. It also serves to express an opinion shared by physicians in general that sulfanilamide should only be given to those patients having an infection that threatens their lives, or is likely to produce serious complications. If the drug is taken indiscriminately by individuals, and drug sensitivity results, it may be impossible to give sulfanilamide in the future when it is definitely indicated as a life-saving measure.

Various types of skin eruptions occur as a result of sulfanilamide. These eruptions often appear along with drug fever. The skin lesions may simulate those occurring in measles and scarlet fever. Intense itching of the skin may be present. There may be hemorrhages into the skin. Angioneurotic edema has been described. With the first appearance of the eruption, no further sulfanilamide should be given. Skin lesions may present themselves at a subsequent time when only one dose of the drug is given.

A more subtle toxic manifestation of sulfanilamide is liver dysfunction. This may or may not be accompanied by jaundice. In a few reported instances, the damage to this vital organ has been so severe

that the patients died. Whether the temporary liver dysfunction that the majority of patients have while taking sulfanilamide results in any permanent damage will depend upon further investigation.

One of the most common signs of sulfanilamide toxicity is anemia, or the destruction of red blood cells in the circulating blood. This usually happens after the drug has been taken for several days. In the majority of cases, this destruction of cells is only of moderate severity, but not infrequently there may be a sudden and precipitous drop in the level of hemoglobin, endangering life if drug therapy is not discontinued. This acute destruction of red blood cells is apparently another expression of drug sensitivity, since the patients who have exhibited this phenomenon may have the same reaction when an initial dose of the drug is given several months after the first reaction.

A more serious form of blood dyscrasia resulting from sulfanilamide is a disturbance in the formation of the white blood cells. In common with other toxic signs, this decrease in the number of circulating leukocytes emerges after patients have ingested the drug for several days. When the level of white blood cells does drop below normal, sulfanilamide therapy should be suspended at once. One of the most feared of all complications in this respect is agranulocytosis, wherein there is a failure of the bone marrow to deliver leukocytes to the circulating blood. This condition is highly fatal.

Other toxic expressions of sulfanilamide have been encountered, but they are less common. Among these is neuritis. Optic neuritis with blindness has been recorded, as well as neuritis of the peripheral nerves. I have dwelt at length on the toxicity of sulfanilamide for the human organism in order to emphasize the inherent danger in the injudicious use of the compound. I believe that you will agree with me when I state again that self-medication is to be deprecated.

As was anticipated, new derivatives of sulfanilamide have been synthesized, and used in the therapy of certain infectious diseases. In May 1938, Dr. L. E. H. Whitby of London announced that a new derivative known as sulfapyridine was more effective than sulfanilamide in the treatment of infections due to the pneumococcus. The most prevalent type of infection caused by this organism is pneumonia. It is also the etiological agent of a severe and fatal form of meningitis. Although statistics for pneumococcal pneumonia have shown a reduction in the mortality rate following the widespread use of immune serum, there is still considerable room for improvement. Sulfapyridine has proved to be an effective therapeutic agent for this type of pneumonia. It is relatively easy to administer, and is less costly than serum. This does not mean that the use of serum has been abandoned. There is some evidence that in the more severe cases of pneumonia, the combined employment of immune serum

and sulfapyridine is more efficient than either one alone. Furthermore, there are some individuals who cannot tolerate sulfapyridine because of its toxicity. Treatment of pneumococcal meningitis with sulfapyridine has been productive of most encouraging results.

Sulfapyridine has also been successfully applied to the therapy of staphylococcal infections. Treatment of this type of infection with sulfanilamide was largely ineffective. Sulfapyridine has also been useful in the treatment of gonorrhea. Patients whose infections are resistant to sulfanilamide therapy may be cured with sulfapyridine.

Sulfapyridine precipitates toxic signs and symptoms that make it a disagreeable drug to prescribe at times. The compound is more insoluble than sulfanilamide and, therefore, is absorbed erratically from the intestinal tract. This factor of absorption is important because successful therapy depends upon an adequate amount of the drug in the blood and tissues. Sulfapyridine also causes severe nausea and vomiting in many patients, so that it may be impossible to continue giving it. Another toxic manifestation not shared by sulfanilamide is that acetylated sulfapyridine crystals may be precipitated along the genito-urinary tract causing serious kidney dysfunction and pain. In addition, sulfapyridine results in other toxic signs that have been described for sulfanilamide.

What of the future of chemotherapy? Hundreds of new chemical compounds have been synthesized, and are being investigated in many laboratories. It is not unlikely that drugs less toxic for the human organism, and just as deleterious, if not more so, for bacteria, will be available in the future. At the present time, we are investigating a new preparation at the University Hospital called sulfathiazole. In conclusion, I have endeavored to present to you a general review of this new form of chemotherapy. It is a rapidly developing field and, perhaps in the near future, much of what I have said will be only medical history.

THE FUTURE OF FLYING [1]

By H. E. WIMPERIS, C. B., C. B. E., Hon. D. Eng. (Melb.), Past President Royal Aeronautical Society

President of the Engineering Section, British Association for the Advancement of Science

The presidential address to the Engineering Section of the British Association provides each year an opportunity for a survey of some aspect of engineering science which happens to be of especial importance at the time it is given, and often one which the experience of the president of the hour may chance to render especially appropriate. My subject today is "The Future of Flying." Of its importance at the present time there can assuredly be no doubt. Aviation is surveyed by the public with a tempered pride—pride, it is true, in man's achievement, but apprehension, it is equally true, as to the use which is being made of it.

The aspiration toward winged flight was expressed, I submit, with great wisdom when, more than 2,000 years ago, the Psalmist avowed his longing for "wings like a dove!" How wise a discrimination is revealed by the poet's asking not merely for the power of flight but that his wings shall be "dovelike." For the space of a generation mankind has possessed the power of flight—a marvelous scientific and technical triumph but, alas, incomplete. Brilliant as was the work of the brothers Wright, the crown of achievement will not be truly won until a grateful mankind sees that the wings gained are the wings of a dove and not those of a bird of prey.

This is the challenge to our age. One generation has solved the mechanical problem, leaving it to the next to solve the moral one.

Ever since man inhabited the earth he has lived not by his physical powers, which are slight, but by the exercise of his wits. Every new invention he has made has had its warlike use as well as its peaceful purpose, and each has challenged his wits to ensure that good rather than harm shall result from the new discovery. To bend the newest invention of all, the conquest of the air, to the service of mankind is now his great task. In it, success is essential lest we presently

[1] Address to section G, Engineering, of the British Association for the Advancement of Science, Dundee Meeting, 1939. Reprinted by permission of the Asssociation, from The Advancement of Science, new quarterly series No. 1, October 1939.

find that it is the air that has conquered mankind rather than mankind the air. Before we can regard the conquest of the air as achieved we must control the warlike menace.

In our own technical field, we as engineers have long been used to responsibility, to pioneer work, to expert status. But when it comes to the social application of our inventions, we are responsible not in our capacity as engineers but as ordinary inexpert citizens; and here we have been very conscious of our amateur status. We are not experts in the social application of our work; and we are but a handful among millions. This has been the view of the last generation—though held with increasing uneasiness, as the misuse of our inventions has become more apparent.

But is it possible that the conditions which formed this view are changing? May it be claimed—I think it may—that we as engineers, as technicians, have an important contribution to make toward the peace of the world?

I believe that the scientific advances of the present time, and their probable development in the near future, will help us to solve, and not to aggravate, our central problem—the task Lawrence of Arabia spoke of as "the biggest thing to do in the world today"—to bend the newest invention of all, the conquest of the air, to the true service of mankind.

Mechanical flight was achieved when Wilbur Wright flew in December 1930 in that odd-looking machine now so proudly housed in the Science Museum at South Kensington. It certainly does look a queer machine to modern eyes. Although the engine weighed 180 pounds it gave but 12 horsepower! Of course it was natural that this, like all the other early airplanes, should be built with two pairs of wings. Engineers were well accustomed to carrying bending moments by a form of girder construction having an upper and a lower boom, and in the biplane form of construction the loads could be carried in this familiar way. Such early trials as were made of the monoplane type merely seemed to confirm the idea that a strong wing structure could not thus be found, and the biplane became the accepted type. Speeds in those days were low, and even long after the Great War it was thought that the attainment of high speed would be mainly a matter of putting in more and more engine power. More and more power was accordingly put in. This led indeed to the achievement of higher speeds, but far-sighted designers saw that there was a limit to the extent of progress by this means. But, as a Spanish proverb has it: "When one door shuts another opens." The new door in this case proved to be the streamlining of the external form of the craft as a whole.

That the cleaning up of the aerodynamic structure could carry performance much farther than had hitherto been realized, and do so

without any increase of engine power, was first clearly pointed out, little more than 10 years ago, by Prof. B. M. Jones, of Cambridge. This required that all excrescences should be removed, and of these some of the worst were the interplane struts and wires. When that had been achieved, it was realized that much of the equipment hitherto carried externally, especially in military types, must be put inside, and with that attained, after a severe struggle, there arrived the modern streamline airplane with its undercarriage, and even its tail wheel, retractable into the body of the structure. What yet remained was attention to those external surfaces scrubbed by the passing air stream. Here guidance was given, curiously enough, by the experience of sailplane pilots, who had long found that a much better gliding angle was attainable when the surfaces were not merely made smooth, but were carefully polished, and even dusted before flight! At the time these minutiae of housemaid's care seemed fantastic, but experience, both within wind tunnels and without, showed that the sailplane pilots were right and that protuberances on a wing no more than a thousandth part of an inch high produced a measurable drag.

FLYING TODAY

The consequence of these and other changes in design from the original Wright machine brought a steady growth in speed, which during the last score of years has increased by an average of well over 10 miles an hour in each year.

This over-all increase in airplane performance is indeed impressive: in speed from the 31 miles per hour of the Wrights to the 469 claimed today! Behind the change in external characteristics there have been internal changes of an equally important character, such as the increase from the Wrights' wing loading of 1½ pounds per square foot to the figures of today when 20 to 30 and 40, and even more, are common. There has also been an equally impressive change from the modest engine power of the Wrights to the four-figure powers of modern practice.

As far as growth in altitude and range of flight are concerned, further progress must depend chiefly on improvements in the present-day materials of construction, or in the discovery of entirely new ones. At the moment dural is found best, not because it has any higher ratio of strength to density than alternative materials, for in that respect it differs little from steel, or even from cotton or reinforced plastic; but because in comparison with steel its lower density (little more than a third) enables thicker and therefore stiffer and more fool-proof sections to be used. But, as in the case of steel construction, the sections have to be fastened together with innumerable rivets (more than a million in one "Golden Hind"), and this time-

absorbing process is both intricate and costly. If some improved reinforced plastic could be used instead, the path of the manufacturer, once he had learned the art, would be much simplified.

Speeds have grown because of the smoother shapes used in construction and through the greater engine powers provided. Can speeds continue to rise indefinitely? We may have gone almost as far as we can in using ship-shaped forms, though we still know very little about the possibility of insuring an increase in the extent of the laminar flow of the air over the surface of wings or body. If this could be done the resistance would drop considerably. As far as prospective increases in engine power are concerned there is little publicly revealed in these days, but one hears of testing plants being adapted to deal with engines of no less than 3,000 horsepower apiece. But even with these increases a definite speed limit is being approached—not one imposed by the laws of any State but by the laws of Nature. As I pointed out 2 years ago in a presidential address to the Royal Aeronautical Society, there is good reason to believe that although speeds of 500 miles per hour may be attained, it is unlikely that 600 will be much if at all exceeded, for the latter figure is some 80 percent of the speed of sound, and when the latter is approached the drag rises to a level far ahead of any prospective engine improvements. Although nothing in the physiology of man forbids even higher speeds, as witness the high orbital speed of the earth on which we all live with some measure of tempered comfort, there is soon imposed a physiological limit if high speed is combined with rapid maneuver. If the latter is required, then the speed must be controlled to suit the conditions. Only the future can reveal how the balance between the two will be struck.

No simple summary can be given of what has been done as regards engine development, for great as has been the change from the 15 pounds per horsepower of the original Wright engine to the 1 pound, and less, of today, one remembers that in this one respect the engines of the last Schneider Trophy Race were as meritorious; where the latter were much below modern standards was in their lack of reliability when working at this power ratio. Today's engines run without attention for hundreds of hours, a very different matter from endurance for a short race.

Even if engines of 3,000 horsepower may be said to be in sight, they are still some way from achievement. Progress depends not only on the skill of the engine designer and the metallurgist, but on the ingenuity of the industrial chemist in producing his remarkable fuels, wonderful alike for their uniformity of quality and for their ability to resist detonation even when employed in engines of very high compression ratio.

The outstanding constructional change today is the employment on a large scale of the sleeve valve, particularly as developed by the great Bristol firm. This has the impressive merit of only needing half the component parts of the old type poppet-valve engine; moreover it is found that, with a given fuel, it can operate without detonation at an appreciably higher compression.

Engines today run safely at far higher speeds than of yore, and they are cooled in different ways and at a much less expense in air drag than used to be the case. In fact at the highest speeds the drag offers some theoretical promise of being replaced by a small thrust! A new cooling problem will arise, however, when pusher airscrews become as common as they will once their use is shown to afford a means of substantially decreasing wing drag.

Improvement in load-carrying capacity depends also on improvements in materials, though it is fair to designers to record the progress made in reducing the percentage which the structure forms of the total flying weight in modern aircraft. Nowadays as good a figure is shown for this in large flying boats as in landplanes, a remarkable achievement. The flying boat used to be thought of as slow and heavy, but today it holds its own in efficiency, whether aerodynamic, structural, or economic, with any other mode of flight.

The flying boats of today represent a great technical advance in quality over their predecessors of 10, or even 5 years ago, but they have not yet shown any marked advance in size. The fine fleet of Empire flying boats is made up of 20-ton units; the new Short "Golden Hind" class for the Atlantic weigh 33 tons apiece; the Boeing "Yankee Clipper" has a total weight of nearly 40 tons; but the Dornier Dox which long preceded them ran to 50 tons laden. On the other hand there has been a great gain in speed and in carrying capacity. The Boeing boat, for instance, is reported to carry 10,000 pounds of load over and above its 4,000 gallons of fuel. As this amount of fuel will weigh 30,000 pounds, this makes a total load of 40,000 pounds, or almost exactly half of the total flying weight, the same as for the "Golden Hind," and a truly remarkable percentage. The improved Empire flying boats intended for the Atlantic crossing are planned to take off at a flying weight of about 20 tons and to take 3 tons additional fuel after they are air borne—by supply from a flying tanker on Sir Alan Cobham's scheme. This will increase the load on the wings from 30 to 35 pounds per square foot and may be regarded as a first step toward what could be done with wings specially designed and stressed for high loading. The "Golden Hind" class is designed for a range of 3,400 miles without refueling, and this with full load. Its early program may include a survey flight along the route to Latin America.

An attractive development in flying boats is the provision in the Dornier DO.26 of retractable wing-tip floats which fold inward into spaces in the wing. This is a 20-ton machine with two tractor and two pusher airscrews. It is a promising move in a very much desired direction. The remaining structural feature to be made aerodynamically clean is the "step" at the hull provided for ease in taking off. It is no doubt difficult so to design a hull as to be equally efficient whether on the water or in the air, but designers will not be happy until they have satisfied both requirements.

It is naturally impossible in the course of this address to discuss all the many problems in the science of aeronautics which are being investigated at the present time. They are far too numerous and the time too short. But to some of them I must refer. One of great importance and quite fascinating interest is the investigation of the change in the air flow over a wing surface from the laminar to the turbulent state. It is known that if the flow could be kept laminar the drag would be vastly reduced, but it has yet to be discovered how to do this. A step in the right direction may lately have been made at the Langley Field Laboratories, for during Dr. Lewis' recent Wilbur Wright lecture before the Royal Aeronautical Society mention was made of some wind-tunnel tests in which a special form of airfoil gave a drag coefficient figure of only about one-third of that usual. Further particulars will be awaited with interest. Many laboratories and experimental stations are studying this same problem, and, as not infrequently happens in such cases, success once met with, itself creates a batch of new problems. For one thing it is clear that the presence of laminar flow can but be hindered by the use of the tractor type of airscrew now almost universal. It may be necessary to change to pusher designs, and as this will involve a marked rearward movement of the center of gravity of the whole aircraft, all the stability factors will be gravely affected, to say nothing of the many engine problems also raised.

Other special problems relate to the possibility of having wing areas adjustable in flight by telescopic or other means, to the study of the very considerable increase in the control forces required of the pilot in large machines of high speed capacity, of the special problems raised by variable-pitch airscrews, particularly in relation to the landing run, of the advantage at high air speeds of two-speed gear boxes, and of the special problems involved in pressure cabins.

The problem of the rotating wing is in a class by itself. Aircraft so fitted are quite unable to compete in speed with those with normal wings, but they easily beat the latter in take-off and landing. Many types are now in the field, the Cierva, the Hafner, the Kay, and the Focke, to mention no others. The scientific problems are largely solved, as are the great mass of the mechanical ones. What is

required is such a degree of user as will call for this form of aircraft to be constructed in numbers. When that happens, rotary-wing aircraft will benefit in their design by that skilled attention from the production engineer which alone seems able to produce results that really look right.

The growth in recent years of the interest taken by the public in aviation, over land and over sea, is most striking. Partly, of course, it is due to the increase in the Air Arm and all that is thereby implied. But there is also a very rapidly growing use being made of the abundant facilities for air travel offered by the civil air-transport services. The United States is often thought to lead the world in this respect—as it certainly does in the use of the automobile—but I believe that in proportion to the size of the population, and that is the true criterion, the total mileage flown annually is larger in Australia than it is in any other single country in the world. And there is good reason to expect that that preeminence is likely to continue.

THE FUTURE YEARS

Let us consider what lies ahead in the coming years in respect of speed, size, and range. No doubt military craft will go as fast as they can. But since it seems that they cannot exceed 600 miles per hour much if at all, there is little doubt that speeds between 500 and 600 will become usual. Not so, however, for the civil air services, where quiet, comfort, and cost are all-important. Here there is good economic reason for speeds to settle down in the 200 to 300 range. In both these classes we seem therefore to be approaching some degree of finality.

Altitude and range are alike in that so much depends on the discovery of new materials of construction and new ways of using them. Steady progress may be expected, though probably nothing sensational unless the use of reinforced plastics be so reckoned. For civil work the advantage of long-range flying depends on the ability to fly by night, and this is advancing rapidly. Radio services are improving and the vagaries of the ionosphere are becoming better understood. High-altitude flying—whether in the stratosphere or just below it—requires the sealed cabin, and it will, I fancy, chiefly be sought by those whose first care is speed and whose lesser concern is cost.

When, however, we come to think of such other factors in the future of flying as the size of the craft, and the wing loading employed, we are concerned with quite other considerations. Size depends mainly on engine power, for there is a limit to the number of power units which can be conveniently looked after. Even if we have tractor and pusher airscrews in tandem (and tractor screws

may well become unpopular where the highest aerodynamic efficiency is sought), 6 such pairs may be the practicable limit. This would give us 12 engines, which, at 3,000 horsepower apiece, makes the total power 36,000. At 15 pounds carried per horsepower available this would give a total flying weight of 540,000 pounds or some 250 tons. Such a craft would naturally be a large boat, taking 200 passengers or more; and that is the largest flying craft that can be said to be now in sight, although I ought perhaps to mention that in a lecture to the students of the Royal Aeronautical Society, who alone perhaps might be expected to live to see it, Dr. Roxbee-Cox was bold enough to include an American forecast for a boat of 3,120 tons. But difficult as it may be to foretell accurately the future of the large flying boat, there can be little doubt that we shall soon see such craft in active competition with their older rivals—which use the surface of the sea—for all rapid passenger transport on the important Atlantic routes.

The future of wing loading is hard to forecast. As has been mentioned, the early Wright airplane was loaded to 1½ pounds per square foot. By the time of the Great War this had risen to the neighborhood of 10 pounds, but even Hallam ("Pyx"), writing a few years later of his vision of a 200-ton flying boat, did not put it above 8! In the succeeding years, however, the figure has grown gradually until it is now in the neighborhood of 30; and while loadings of 40 to 50 are talked about for future craft, Sir Allen Cobham has suggested that, provided the bulk of the fuel is added by refueling in the air from a tanker, loadings as high as 60 or even 70 should not be unattainable. The real limiting factor here is the take-off and the landing. With landplanes, the disadvantage of high loadings is that they lead to great increase in the size and cost of airdromes, unless this can be avoided by the use of an auxiliary like the Mayo Scheme or by some form of catapulting, or by the use of the "tricycle" undercarriage, now so rapidly coming into use. This consequence of high loadings does not apply in the same degree to the flying boat, but even there it has the disadvantage of requiring the use of natural harbors of large size with not too much local water traffic.

Can one, however, relate these speed ranges of 500 to 600 for military craft, and 200 to 300 for civil, with wing loading, with or without refueling in the air? We have the relationship that the minimum air speed of flight is measured by the square root of the wing loading. If we assume the use of such aids as wing flaps, we can calculate for sea-level conditions just what the stalling speed for any given wing loading must be.

For a take-off speed of 100 miles per hour (i. e., stalling speed of 80) the wing loading would be about 40 pounds per square foot, suitable for civil types having a top speed of, say, 300 miles per hour (since the take-off and landing speeds would then be about 100). But once in the air a much larger load could of course be carried.

In the case of military types having top speeds of 550 miles per hour or thereabouts, the landing speed could hardly be less than 150, giving a wing loading of 100 pounds per square foot. It looks therefore as though in the coming years the wing loadings for civil types will go little beyond what is now planned in many drawing offices, but in the case of military types the present-day figures may certainly be doubled unless some new wing arrangement can be discovered which will greatly reduce the loading figure when a landing is about to take place. Rotating wings are the perfect solution for the landing problem, but how to combine them with means for the attainment of high horizontal speed is a problem which the future has yet to solve. The one recent development—or revival—which seems to promise a great advance in safe landing is the tricycle undercarriage, the use of which seems to be almost all pure gain. In a lecture before the Royal Aeronautical Society last year H. F. Vessey expressed the rather conservative view that although with landplanes of the normal type it is difficult to see any considerable increase in wing loading at landing above about 30 pounds per square foot if present restrictions on landing distances over a barrier are to be maintained, nevertheless he admits that by the use of the tricycle undercarriage the loading might go as high as 40.

It is odd that chance should decide—or at least appear to decide—the future of so many forms of human activity. Almost at its birth, broadcasting in Great Britain fell into good hands, and the cinema into bad, but aeronautical research, very fortunately, into good. I can imagine a critic remarking that it was not quite all chance, and that organized aeronautical research owed much to the wise foresight of the late Lord Haldane, who caused there to be created an Aeronautical Research Committee with funds for research workers and apparatus for them to use.

Fortunate it was indeed that research in aeronautics was so wisely led and adequately supported. It was a new science, and one of the few happy results of the Great War was that it drew into this service some of the most brilliant young scientific men of the day, especially from the universities of Cambridge and Oxford. And this interest held, for even now the leaders are largely drawn from that band of

pioneers. In their early work they were happy in their hour, for almost anything that was done was necessarily original and almost any invention was bound to be new. There was little need to consult the records of the past. The Aeronautical Research Committee was, and still is, mainly drawn from these men and those they have trained. With the support and confidence felt in them by the Government, they were able to develop ideas, whether arising from their own ingenuity or from workers and industrialists outside. It was an example soon followed by the United States, and its latest adherent is Australia, the newest country to take up aeronautical engineering as a serious national effort.

It is impossible not to be struck by the stimulus which this specially directed scientific research work has given to other branches of engineering. It represents the spearhead of attack in applied science, since so many of its problems arise from practical conditions of unusual difficulty, owing to the intensity of the desire for light construction combined with strength and durability, and for very high efficiency factors. It is hardly surprising therefore that such apparently nonaeronautical fields as the design of steam turbine blades, of power boats, of industrial fans, of light vehicles should owe so much to the results of aeronautical research.

THE AIR ARM

Among the world's many political preoccupations there is no more pressing or more intractable problem than that of curbing in some way the universal growth of armaments. It is true that insofar as the product is entirely produced within the country of origin the mere cost is of little moment. One makes armaments instead of making something else, and in the case of a people who loved above all having lots of lethal weapons there would be nothing more to be said, though the taste might be thought odd!

It is not, however, solely a matter of finance, since normal peoples would much prefer the energy directed to armament production to be given to articles of service in civil life such as houses, pictures, sailing boats, holiday camps, and the like; and for the general body of such activity to be guided into channels which fit in with the quantity and quality of the labor available in the country. Moreover, just as a house containing a store of high explosives is not looked on as a happy abode, so there is always a fear that in highly armed international life a trigger in some remote spot may be pulled by accident, or by mischief, with irreparable harm to the whole world.[2]

When some years ago an effort was made to come to an international understanding about air armaments, success was not attained. This

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[2] This trigger was pulled a few days after this was written.

was due, it is true, in some measure to the existence of strong professional interests and to the relative lack of attention to the needs of the ordinary man, but it was due also to the inherent difficulty in the then state of the art of distinguishing between military and civil types. Even suppose, it was asked, that one could abolish all military aircraft, how would one deal with the civil types which could be so easily converted. In those days this was a germane question. But is it now? I think not, and for this reason.

The speeds of military aircraft are now in excess of 400 miles per hour and will rise still higher. But civil aircraft rarely go faster than 250, and it is doubtful whether it is economically advantageous to have even so high a speed as that. This at once makes a great difference in the types. Again, the comfort and space needed for civil transport tends to produce a design of body which does not in the least resemble military requirements. Insofar as the civil types in their really large sizes come more and more to take the flying-boat form, so are they the less like military types. Perhaps I should say here that I am leaving aside reconnaissance duties and troop carrying, and thinking mainly of the aggressive type, the bomber.

Hence, as I have previously suggested in a recent address at Chatham House, the position has been reached when, so far as technical considerations are concerned an agreed limitation could be set on military production without the effort being nullified by the existence of civil types to which no such limitations applied. It must be remembered, however, that when a political man talks about "parity in the air" he may not really understand what he is saying. What he probably means is equality in offensive force, for mere parity in numbers might be got by the absurd equation of putting 100 bombers plus 1,900 interceptor fighters as equal to 1,900 bombers plus 100 interceptors, because both sides add up to 2,000. It cannot worry any peace-loving country if one of its neighbors builds 1,000 or 10,000 interceptor fighters any more than it would if that neighbor built immense numbers of antiaircraft guns and searchlights. In fact, as a gain to the general strength of defense it would be rather comforting than otherwise.

The right way to arrive at a proper balance of air armaments is to seek reasonable parity in respect of bombing aircraft and leave everyone free to build as many defensive aircraft as they care to afford. Civil types, by reason of their low speed, would be incapable of acting as fighters, and would be speedily shot down if they tried to act as bombers.

The discovery of the art of flight has certainly raised terrible problems, but it does at last seem as though mankind is beginning to see his way out of the morass. That the laws of nature impose a

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speed barrier is a fortunate thing, for that suggests some finality to the development of types, and limits, moreover, any uncomfortable rivalry with the speed of response of the human body. It is fortunate, too, that this speed limit is much above the economic limit for civil machines, for that means that the civil type can easily be defeated if it tries to play the corsair. And it most blessedly happens at the same time that the strength of antiaircraft defense from the ground and in the air is increasing in effectiveness at a rate that even the optimistic had hardly hoped. Britain, a fortress in the sea, must become a fortress in the air!

In my view there will be no reason, once the international situation has cleared, why there should not be an agreed limitation in respect of numbers of tonnage of bombing aircraft—leaving the interceptor fighters entirely aside. It would be but cautious to agree on a limit to the speed of civil types, but as this would merely confirm what economic requirements would themselves suggest, it need be no hardship; excessively high speeds for civil types do not pay, are much more dangerous to passengers, are much more noisy to everyone, and need wasteful forms of airports.

When this difficulty of our own age has been at last happily solved, we may be very content to leave our successors the even more threatening menace of dealing aright with the problem of atomic energy. This it is not necessary for me to describe. I will only say that in a recent broadcast address Professor Cockroft spoke of an atomic trigger action between the metal uranium and a single neutron which is reported to be capable of releasing a 100,000,000-fold increase in energy. Perhaps there are immense practical difficulties in doing this on a large scale; I earnestly hope there are. For ourselves we are quite sufficiently occupied with our own problem, how rightly to guide the future of flying.

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